ECONOMIC BOTANY

DEVOTED TO APPLIED BOTANY AND PLANT UTILIZATION

A Publication of
THE SOCIETY FOR ECONOMIC BOTANY

Biology, Food, and People — *Paul C. Mangelsdorf*

Cultural Factors in Food Consumption; An Example from India — *Edward B. Harper*

The Rockefeller Foundation Program in the Agricultural Sciences — *L. M. Roberts*

Progress in Biochemical Engineering Broadens Our Choice of Crop Plants — *N. W. Pirie*

Folk Uses and Commercial Exploitation of Aloe Leaf Pulp — *Julia F. Morton*

Corn's Evolution and Its Significance for Breeding — *Walton C. Galinat*

Buchu, A New Cultivated Crop in South Africa — *Howard Scott Gentry*

Seed Technology — *Duane Isely*

The Freezing Preservation of Vegetables — *M. A. Joslyn*

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Book Reviews

Herbicides and the Soil. Drogenkunde. Plant Growth Regulation. Fats and Oils: An Outline of Their Chemistry and Technology. The Australian Environment. Politics and Grass: The Administration of Grazing on the Public Domain. Studies on the Physiology of Bamboo with Reference to Practical Application. Pulp and Paper: Chemistry and Chemical Technology. Vol. I: Pulping and Bleaching. Weed Identification and Control in the North Central States. Plants That Changed the World. A Bibliography of Eastern Asiatic Botany. Supplement I. Yearbook of Forest Products Statistics, 1960.

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Biology, Food, and People[1]

PAUL C. MANGELSDORF[2]

It is always somewhat difficult to discuss the world food problem with an American audience, for here in the United States we suffer not from the shortage of food but from an embarrassing surplus. The United States is probably the best fed nation in the world today, if not in all of the world's history. Indeed, the United States might better be described as the world's most overfed nation. Our food surplus has actually become a hazard to public health. Some years ago at the annual convention of the American Medical Association one of the principal speakers contended that our most critical health problem today is not polio, not cancer, but overweight. He estimated that, even at that time, the population of the United States was overweight in the aggregate by 500,000,000 pounds.

Hunger, an Enemy of Peace

But the United States is only a small part of the world and with respect to food almost a unique part. When we look at the world as a whole, it is quite clear that the problem of food is one of the world's most acute and pressing problems and is directly or indirectly the cause of much of the world's present unrest. It is now generally recognized that hunger is a powerful enemy of peace. This was clearly stated by the Roman philosopher, Senaca, more than 2,000 years ago when he said, "A hungry people listen not to reason, nor cares for justice, nor is bent by any prayers."

Today two thirds of the world's people are inadequately fed by modern nutritional standards and are suffering from chronic malnutrition. To understand what this situation means one almost has to go to such a country as India. There the food supply is so precarious that when drought, floods, or early frost strike any part of the country there would be famine and mass starvation if the central government did not move in quickly. The near-famine areas of India are usually strongly Communistic and all of India may well move toward Communism—not because its ideology is so appealing to the Indian temperament but from sheer desperation —from the erroneous belief that anything would be better than that which they now have.

Now there is nothing new in human hunger. There has probably never been a time in the history of the world when a substantial part of the world's population was not suffering from hunger or famine. What *is* new is that modern methods of communication and transportation have made this *one* world, if not politically at least to the extent that hunger, poverty, and political chaos in any part of the world represents a potential danger spot to other parts of the world and especially to countries like the United States which have more than they need. It is our very abundance which accounts for the mixed emotions with which other parts of the world regard us. On the one hand we are envied, respected, admired; on the other hand we are feared and disliked by the less affluent peoples of the earth.

The Food Problem of an Affluent Society

The vast differences between our living standards and those of even our closest

[1]Presented at Second Annual Symposium of The Society for Economic Botany: *Integrated Research in Economic Botany II. Nutrition for an expanding world population.* Massachusetts Institute of Technology, Cambridge, Mass., May 14, 1961.

[2]Botanical Museum of Harvard University, Cambridge, Mass.

neighbors in this hemisphere may be epitomized by comparing two food mixtures which have recently come on the market. In Guatemala, Dr. Nevin Scrimshaw has developed a food supplement for children which added to present restricted diets will provide proteins, vitamins, and minerals in quantities which they require irrespective of what else they eat. This mixture will sell for about 10-15 cents per pounds. Here in the United States one of our pharmaceutical firms is making millions of dollars by selling a similar mixture called Metrecal which provides proteins, vitamins, and minerals but which is low in calories and thus enables overweight people to reduce. This sells for two dollars or more per pound depending upon the size of the packages. In other words, we can afford to pay and do pay 15-20 times as much to keep our weight down as Guatemalans can pay to keep it up to a bare minimum.

There are many of us who believe that the problem of hunger in the world is one to which we well fed people must give attention, if not from compassion then from our own enlightened self-interest. We must do what we can toward helping to solve the world's food problem. Let us examine the problem and try to see what its real nature is and what we as biologists can contribute to its solution.

Malthus on Population Growth and Food Supply

The problem is fundamentally simple and needs no elaborate statistical treatment to illustrate it. It was clearly defined by the Reverend Thomas Malthus who in an essay first published in 1824 and later in 1830 argued that human populations, like all other living things, are capable of increasing at fantastic rates unless held in check by natural forces such as hunger, famine, and disease. Populations, Malthus stated, have a natural tendency to increase by geometric progressions, i.e., 2, 4, 8, 16, etc. Food production on the other hand can only be increased by arithmetic progression, i.e., 1, 2, 3, 4, etc. Consequently, unless man voluntarily restrains his own reproductive capacity it will eventually be done for him by natural forces always operating. Malthus, unfortunately, incorporated into his essay some harsh social theories which are not acceptable today so that in some circles he is better known as the father of regressive social doctrines than as an expositor of some fundamental principles of population.

Still Malthus is good reading for biologists today not only because of what he had to say about the population problem but because of his great influence on Charles Darwin. It was from Malthus that Darwin received the inspiration for his own ideas on the struggle for existence and survival of the fittest, culminating in his theory of natural selection. Malthus is easily available in a paper-back book entitled "Three Essays on Population." (Mentor Book, New American Library, 1960) The other two essays are by Julian Huxley and Frederick Osborne. All three essays are excellent, and together they present a clear picture of the population problem.

I think that as biologists we can all agree that the first of Malthus' principles is absolutely valid. How many calculations have various people made on the prodigious capacity of living things to reproduce themselves? How many days, for example, for house flies to create a mass of flies greater in weight than the earth itself if each fly could reproduce to full capacity? All that Malthus really added here was to show that human beings resemble other living things in their prodigious capacity to reproduce. It should not be difficult for any biologist to accept this principle. Malthus calculated that the human race, if freed of all restraints, would double its numbers every 25 years. His figures have subsequently turned out to be too conservative.

Malthus' second thesis—that food production can be increased only arithmetical-

ly—has also proved to be true when applied to a closed system, that is a country which is already cultivating all of its arable land. Malthus' two principles can be illustrated with the two accompanying charts: one (Fig. 1) showing the rate of population growth of the world, the other (Fig. 2) showing the rate at which the production of rice has increased in Japan. Note that the curve representing population growth rises with increasing steepness while that representing rice production rises evenly.

The Accelerating Rate of Population Increase

Never in the world's history has the population been increasing at the rate which it is today. Let me cite a few figures:

Time	*Millions*
Birth of Christ	250-350
700 A.D.	300
1650	600
1850	1200
1950	2400
1960	2900
1990 (estimate)	5000

Not only is the population increasing, but the *rate* at which it is increasing is itself *increasing* rapidly. In 1952, for example, the world's population was increasing at the rate of 60,000 per day; eight years later at the rate of 134,000 per day.

My good friend, Dr. Warren Weaver, has a very effective way of dramatizing these cold statistics. "I presume," he says, "that you had breakfast this morning at about 7 A.M. and that this evening you will have your dinner at about 7 P.M., twelve hours later. When you sit down to dinner tonight, tell your friends to move over and make more room, for at the world's dinner table tonight there will be 67,000 more people than there were for breakfast this morning."

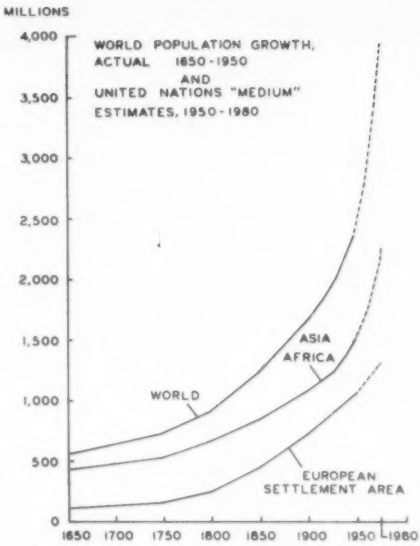

Fig. 1. World Population Growth. From Osborne in "Three Essays on Population." New York.

Mortality Control without Fertility Control

The reasons for this unprecedented increase in the world's population is fundamentally simple: highly effective public health measures, vaccinations and inoculations, sanitation, control of insect vectors of malaria and other diseases have created mortality control with unprecedented rapidity on a world-wide basis without at the same time introducing fertility control. Let me cite one example. It required almost 300 years to eliminate malaria in England. In Ceylon since World War II malaria has been almost eliminated in seven years through the use of DDT against mosquitoes. The result is that the death rate has been reduced by half while the birth rate has actually increased because child-bearing women are not debilitated by malaria and consequently there are fewer miscarriages. The population of Ceylon is now doubling in less than the 25 years which

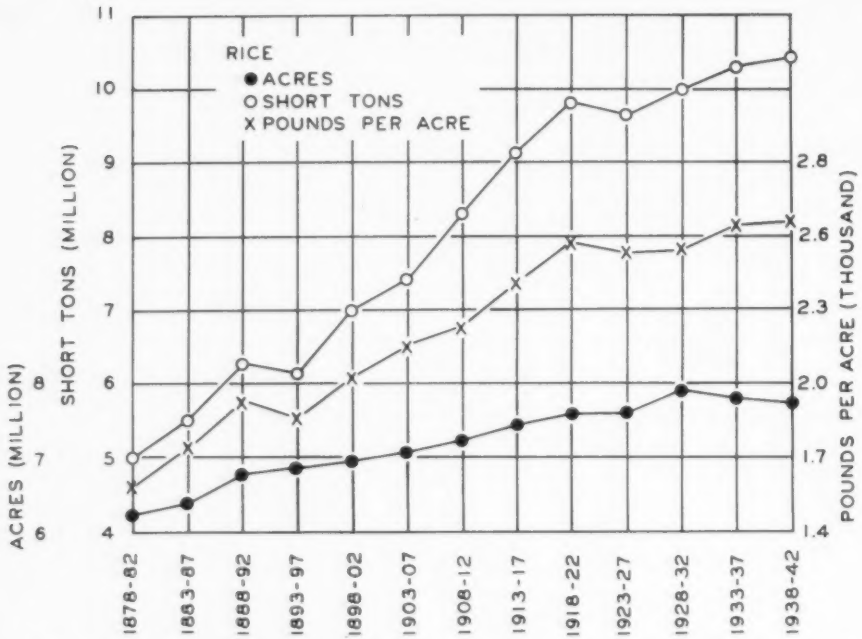

*Fig. 2. Average acerage, production, and yield per acre of brown rice (hulls removed) in Japan by five-year periods, 1878-1942. From Jenkins,*Proc. Amer. Phil. Soc. 95: 1. 1851.

Malthus thought was the maximum rate of doubling in unrestrained populations.

It should be obvious that this kind of increase cannot go on indefinitely without serious consequences, and more and more people are beginning to realize this and to think seriously about it. So today we have a rash of books on the subject, virtually all recognizing that there is a population problem and differing only in the estimates of how serious it is and what can be done about it. The titles of these books are themselves quite revealing.

Thompson	*Plenty of People*
Vogt	*Road to Survival*
Pearson and Harper	*The World's Hunger*
Sir John Russel	*World Population and the World Food Supply*
Shults	*Food for the World*
Fagley	*The Population Explosion and Christian Responsibility*
Clark and Pirie	*Four Thousand Million Mouths*
Sax	*Standing Room Only*

What are some of the possible solutions to this problem, a problem which is now recognized as being scarcely less serious than that of an atomic war?

The solutions, like the problem itself, are fundamentally simple although in practice enormously complex. They fall into two principal categories: (1) a reduction in human fertility and (2) an increase in food production. In both of these we, as biologists, can have a part to play.

Primitive vs. Humane Methods of Fertility Control

Until the present generation almost all cultures in all parts of the world have consciously practiced some form of restraint upon their own fertility. The most primitive method still practiced in some primitive societies is infanticide. The polar Eskimos, whose food supply is so precarious that it normally takes two hunters to feed one woman and themselves, regularly destroy at birth part of the female infants. The bushmen of the Kalihari Desert, who have been intensively studied in recent years by the Marshall family of Cambridge and whose mode of life is beautifully described by Elizabeth Marshall Thomas in her book, *The Harmless People*, have shallow graves prepared in readiness for babies born when the food supply is already inadequate. The mother knows that she must kill her baby in that brief moment between the time the baby is born and the time that her love for the baby wells up in her and makes the act impossible forever after.

As human cultures became more sophisticated and more familiar with the human reproductive processes, they turned from infanticide to abortion as the most common means of exercising control over fertility. Until recently this has been the principal method used in Japan where, after World War II, abortion was legalized. The total reported abortions in Japan in 1953 were more than a million. These and unreported abortions are believed to exceed live births in Japan that year. It is by these harsh but effective means that Japan has reduced the birth rate by more than half since World War II. But both infanticide and abortion are terribly wasteful of human energy and are an insult to human emotions. More humane methods must be found.

A third method of fertility control, and in some ways the most promising, is voluntary sterilization. For males this involves the simple, relatively painless operation of vasectomy, tying off the vas deferens. In the female the operation is more difficult. For both sexes it is highly effective and does not affect sexual virility. Several states in India, notably Madras and Kerala, are now officially promoting vasectomy with rather encouraging results. In Puerto Rico more than a tenth, perhaps even a fifth, of the women who have had their third, fourth, or fifth child now arrange for sterilization, although the practice is for many of them in conflict with the teachings of their church.

Finally, we come to contraceptives, and here is where biologists through research on the human reproductive system might make their greatest contributions. Julian Huxley estimates that, if we spent one tenth as much on research on controlling human reproduction as we do on the release of atomic energy, we might have the answer in ten years. The fact is that there is already real progress being made in this area even with the modest sums now spent. Dr. Gregory Pincus of the Worcester Foundation for Experimental Biology has, in collaboration with others, developed an oral contraceptive which, if taken regularly, prevents ovulation in women and seems to have few, if any, deleterious side effects (Science 130: 81-83. 1959). German chemical firms are now manufacturing this or something like it and shipping it by the barrel into Puerto Rico where women are using it effectively. There is real hope, therefore, that overpopulated parts of the world will begin to practice fertility control, and it is a mistake to believe that organized religion is the only or even the chief obstacle to such practice. Five of the countries with the lowest birth rates in Europe are predominantly Catholic countries, and Boston which is more than 75% Catholic has one of the lowest birth rates of any large city in the United States. The Catholic Church recognizes

that there is a population problem and it is not opposed to fertility control *in principle*. Other organized religions, the Hindu, the Moslem, and the Buddhist have no well defined doctrines against fertility control, and a number of Protestant Christian sects actively endorse it. The real obstacles in most parts of the world are not religious but arise from social prejudice, illiteracy, sheer ignorance and poverty, and these involve complex problems, some of them almost beyond the comprehension of the biologist who, in general, deals with relatively simple problems.

It is a fact, I believe, that voluntary population control does not usually begin in a country until a certain level of literacy and living standards are reached. Since most all parts of the world have now accepted measures of mortality control, their peoples must somehow be fed until they learn also to practice fertility control, and here we as biologists again have contributions to make.

It ought to be clear to us that increasing food production without reducing human reproduction will in the long run get us nowhere. Consequently whatever is done in this area must be regarded as a short range solution, a palliative which only keeps the patient alive until effective curatives are forthcoming. Or to use another analogy—one from engineering—increased food production only builds the levees higher to restrain the flood until more intelligent methods are devised for impounding the waters at their source. Nevertheless, in meeting population problems as in flood control, these short range measures are absolutely necessary.

Methods of Increasing Food Production

Of the numerous possible solutions to the food problem about six have been suggested. I give them to you in what seems to me to be the inverse order of their immediate practicability, and on this basis I will altogether omit a seventh idea: that the excess population of the globe be sent off into space to populate other planets.

1. The use of atomic energy in synthesizing food. This is a physicist's solution. The physicists regard food as nothing more than a particular combination of atoms. The atoms themselves are abundant, and the energy to put them together is also abundant and will become more so if the problem of controlled thermonuclear reaction involving hydrogen is solved. All we lack, the physicists tell us, is ingenuity. This all sounds well in theory. So far we have been able to synthesize only minute amounts of foodstuffs in test tubes: carbohydrates, fats, and perhaps proteins or at least their precursors and already, even for present uses, the problem of disposing of atomic wastes is a very formidable one.

2. Use of solar energy. There is plenty of it. If all could be used, it would supply a hundred thousand times over our needs for food, heating, and power. If we could capture and convert it, one square yard of the earth's surface would receive enough solar energy to supply all of man's needs. The trouble is that it is too difficult to capture and, as Sir Edward Bullard has remarked, "It is a good thing for us that it is diffuse, otherwise we should all broil." We do, of course, now employ solar energy in the production of foodstuffs through growing of green plants, but this is a highly inefficient use. A corn field, for example, is about two tenths of one percent efficient.

3. Growing of lower plants for food. All food plants now of any consequence are seed plants, Angiosperms. Can we grow lower plants successfully instead? We now grow fungi in mass cultures to produce antibiotics such as penicillin, streptomycin, and others. Can we harness them for food? We know, too, that algae are far more efficient than higher plants in utilizing energy, and already in this country and elsewhere many peo-

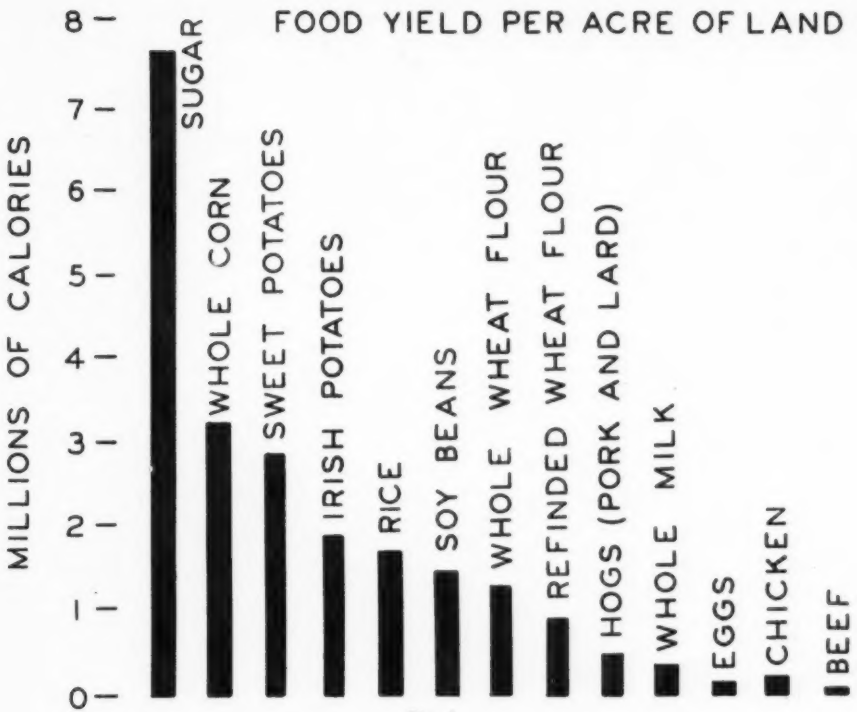

Fig. 3.

ple are doing research on a unicellular alga, *Chlorella,* as a possible source of food. So far costs of production are still too high and the product is not too palatable. However, human beings can learn to eat anything especially when they are hungry enough; and as the food problem becomes more acute, we may find ourselves depending on *Chlorella* or some other cultivated alga for a substantial part of our food supply.

4. Food from our forests. About 25% of the land surfaces of the globe is in forests. The principal product of the forests is cellulose which can be digested by cattle and other ruminant animals but which for man is largely indigestible. Cellulose is built up from sugar and can be converted back to sugar. Edible yeasts can also be grown on the sugar or on the sugar-rich liquors which are byproducts of this conversion. The Swedish people during World War II made good use of these products but quickly gave them up when free trade was again established. The most discouraging obstacle here is that the world's forests are often far removed from population centers. However, I can conceive of the world becoming so desperate for food that hydrolization and fermentation plants will be established deep in remote tropical forests and the concentrated cellulose conversion products, sugar and yeast, will be flown out.

5. Food from the sea. About seventy percent of all solar energy falls on the sea, and a very substantial part of all photosynthetic activity takes place in the sea; yet less than one percent of our food now comes from the sea. There are

several reasons for this, one of the principal ones being that the sea food which we finally consume is the product of many cycles: tiny animals consuming tiny plants, larger animals consuming smaller animals, each cycle perhaps producing one pound of food for every ten pounds consumed. Nevertheless, the amount of food obtained from the sea could be greatly increased if the research spent on marine sources were a fraction as great as that spent on agriculture. It has even been suggested that it might be feasible to strain out the tiny plants and animals which represent the plankton of the sea and use these directly as food. We do need much more research on sea food, in fact upon all aspects of oceanography, than we now have. As Julian Huxley once suggested, "The ocean's bottom may prove to be even more interesting than the moon's back side."

6. Improving our agriculture. Anthropologists tell us that there have been three great revolutions in man's history: the mastery of fire, the invention of agriculture, the use of power (from nonhuman sources).

It has been the improvement in our agriculture, both in quantity and quality, which has so far enabled the world to keep up, at least after a fashion, with the world's explosively expanding population. And it is further improvement in our agriculture which offers the greatest immediate hope of keeping the world fed until widely employed restrictions on fertility begin to come into greater play.

Improving our food supply through improving agriculture is essentially a matter of improving our cultivated plants and their environment. We shall be using fewer animal products as the pressure of population grows. Figure 3, which compares the number of calories produced by various crops with those produced by animal products, is quite revealing. You will note that sugar coming from sugar cane and sugar beets is well ahead of other crop plants and far ahead of animals, especially beef. As the food situation becomes more precarious, we shall certainly be consuming more sugar and paying for this change in our dietary habits by spending more time in the dentist's chair. By consuming less beef we shall probably make a gain in reducing the frequency of cardiovascular disease.

Research Needed on World's Principal Food Plants

During his history man has used at least 3,000 species of plants for food and has cultivated at least 150 of these to the extent that they have entered into the world's commerce. The tendency through the centuries has been to use fewer and fewer species and to concentrate on the more efficient ones so that today the majority of the world's people are actually fed by about 12 species of plants. These include three cereals: rice, wheat, and corn; two sugar plants: sugar cane and sugar beets; three root crops: potato, sweet potato, and cassava; two legumes: the common bean and the soy bean; and two tree crops: the coconut and the banana. If we were to raise the list to 13 species, it would certainly include the peanut.

Since these plants quite literally stand between mankind and starvation, we should know as much about each of them as we do about the destructive agents of the world; as the medical profession, for example, knows about the world's principal diseases or as our aeronautical engineers know about the world's principal bombers or guided missiles. Today we do not have that kind of information, but we are beginning to get it. Take rice for example: Chester Bowles once said that the war for Asia would be won not in the battle fields but in the rice fields. He is absolutely right. At least 50% of the world's people get at least 60% of their energy from rice. Thus, more than 30% of all human energy in the globe now comes from one plant species: the rice plant. It is in realization of this fact

that the Rockefeller Foundation and the Ford Foundation have recently combined forces to set up a ten million dollar rice research institute in Asia. Here geneticists, plant physiologists, mycologists, biochemists, engineers, and others will devote themselves to understanding the rice plant—learning to improve both the plant and its environment.

An interesting development involving agriculture in a new way may come out of research by Dr. Pirie of the Rothampsted Experiment Station in England on extracting proteins from plant species not generally regarded as providing human food. If the method proves successful, we may find parts of the world growing alfalfa and other leguminous forage plants for their protein instead of depending upon less productive leguminous species. It may even be possible to bring species now regarded as unpalatable into cultivation.

Exporting Agricultural Skills

It may be years before these various types of basic research pay off in greater food supply. In the meantime some improvement in the world's food supply can be made by helping farmers in underdeveloped countries to adopt modern scientific methods of farming that have proved so successful in the United States. An outstanding example of this is hybrid corn which has quite literally revolutionized the agriculture of the United States corn belt. And an outstanding example of exporting our own skills is the Agricultural Program of the Rockefeller Foundation in Mexico with which I have had the honor to be connected as consultant since its inception in 1941. Three of us: Dr. E. C. Stakman of Minnesota University, Dr. Richard Bradfield of Cornell University, and I were asked by the Foundation to make a survey of Mexico and to report to the Foundation whether it would be feasible to begin an agricultural program in that country aimed at improving the food supply. Our answer to this question was "yes" with three important qualifications: 1. that the program be confined to the basic food plants of Mexico such as corn, beans, wheat, etc.; 2. that it be staffed by the best people available in the United States; 3. that the Foundation initiate such a program only if if were prepared to support it for as long as 25 years.

A following paper on this program will show what has been done in the Mexican Agricultural Program since it was established in 1943 with Dr. J. G. Harrar, now President of the Rockefeller Foundation, in charge. Here I shall only note that in spite of a phenomenal growth of Mexico's population the food supply has more than kept pace. Mexicans are better fed today than they were 20 years ago. The Rockefeller Foundation now has similar programs in Columbia, Chile, India, and may soon have one or more in Africa. The bottleneck in programs of this kind is finding well qualified personnel in the numbers required.

Increased Food Production Futile without Fertility Control

I must not, however, leave you with the erroneous idea that Mexico's food problem, or that of any other country, can be solved unless there is a decrease in the rate of population growth. At its present rate the Mexican population is doubling every 20 years. We cannot expect to continue to double food production at that rate. The consequences of an ever-accelerating rate of population increase are well illustrated in a recent article by von Foerster (Science 132: 1291-1295. 1960.) and his colleagues at the University of Illinois. The authors have plotted the growth of the world's population from the time of Christ to the present on a double logarithmic scale. The data fit a straight line on this scale with remarkable agreement. The authors conclude from extrapolation of this linear regression that the world population will reach infinity in the year 2027 or to be

precise on Friday, November 13, 2036. The mathematical reasoning involved here is much too sophisticated for me; so I consulted Professor Andrew M. Gleason of the Harvard Mathematics Department who tells me that the formulae used in these calculations are valid and that the calculations themselves are correct but that the initial premise, which is based on now available data, may be unreliable. Yet this much we can say: if the rate of increase of the world's population continues to *accelerate* at its present *ever-increasing rate*, then the world's population may well reach infinity in or about the year 2026 and the authors are correct when they conclude, not altogether facetiously, that the pessimists are wrong again—our great-great-grandchildren will not starve to death; they will be squeezed to death.

In concluding in a more serious vein, I would like to leave you with four principal ideas. 1. The problem of food is with us here and now and not in some remote indefinite future time. It is already an integral part of the problem of the cold war. 2. The problem is not insoluble or faced with insuperable obstacles but no easy and simple solution is in sight. Like other aspects of the cold war, it will require patience, calmness, courage, wisdom, ingenuity, skill, vision, and all the other attributes of an enlightened society which has outgrown its adolescence and reached maturity. 3. There are opportunities for service and rewarding careers in this war against overpopulation and hunger. There are also opportunities for the practice of a new kind of philanthropy, a philanthropy involving our time, our talents, and our experience rather than our money. 4. Finally a failure to solve this problem leaves us with rather frightening alternatives which the younger people here will live to see and which our children and grandchildren will have to endure.

Cultural Factors in Food Consumption: An Example from India[1]

EDWARD B. HARPER[2]

Introduction

In preparing for this talk, I have been thinking about what I, as an anthropologist, can contribute to a panel discussing the subject of "Nutrition for an Expanding World Population." My knowledge is rather restricted; I have a rather typical anthropologist's background, which might be called the "head-of-a-pin-view." By "head-of-a-pin-view-" I mean "seeing "small" but not necessarily "thinking small"; that is, anthropologists tend to know one small population rather intimately and in depth, but rarely is this group even as large as a whole "tribe."

My own major research experience has been concerned with a very small region in South India, an area in which my wife and I worked for a year and half. Consequently, most of what I say will be about South India. I shall begin, however, by making a brash generalization and shall refer to several other cultures.

In all societies there are customs regulating the consumption of food. In some, these are minimal—for instance, Australian aborigines have been noted for their lack of taboos regarding what foods are restricted from their diet, and in the protocol used in its cooking, serving and consumption. The food taboos that they have are primarily related to their kinship system, in which a group of kinsmen often refuse to consume the animal or plant they consider to be their totemic ancestor.

In order to exemplify what I mean by "cultural factors in food consumption," I should like to digress from my main subject matter for a moment and refer to Paiute Indians, who lived in the Great Basin area in the western United States. The culture of the Paiute Indians was unstratified and characterized by a minimal amount of technology. They inhabited a sparse, arid and uninviting environment. While studying Paiute Indians I was impressed by the nearly complete and often ingenious utilization of available food resources. But in contradiction to this I was also struck by the fact that nearly every adult Paiute Indian had a taboo on some type of food that he or she refused to eat. This was in spite of the fact that hunting, collecting, gathering, digging and preparing food was a dominant concern to these Indians, required most of their working time, and still did not yield enough to prevent periodic hardship and even starvation.

In explaining these taboos, two factors need be noted. First, that the food items tabooed to any one individual were, without exception, relatively unimportant in quantitative terms. Also, the precise prohibited food varied from individual to individual. Secondly, it need be noted that this was a culture characterized by technological paucity, almost no accumulated wealth, and the bare minimum of status differentiation. The culture fostered individualism by putting emphasis on economic and social independence, but provided few cultural symbols whereby any one individual's social identity could be differentiated from that of another. It is precisely around these points that the food

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taboos of individual Paiutes can be understood. Not to eat a certain berry, root or insect supplied an individual with a symbol by which he was differentiated from other individuals. Given the importance of the food quest, it is not surprising that it was in this realm that these Indians expressed their individual uniqueness, and, given the difficulty of making a living and their lack of cohesiveness as a tribe, it is not surprising that they did not taboo a food for the whole social group, a pattern which would be more appropriate to a socially cohesive group desiring a symbol by which to express their group solidarity and to give them a "unique" group identity distinguishing them from other similar groups (*e.g.*, as among Australian aborigines).

Hindu Eating Habits — An Example

I shall now return to the Hindu civilization of South Asia to discuss the biological imperative of eating and to examine the specific cultural overlay that impinges upon this universal phenomenon. In this culture food consumption is no simple matter. The requirements for a feast, which we might reasonably think of as an empty belly and an available food supply, do not necessarily result in a feast; among Hindus, as among many other peoples, the values of their culture often take precedence over purely biological needs. Facts such as these must of necessity be dealt with by those who are interested in raising the standards of nutrition of a people.

Food taboos in this Hindu community are complicated to an almost incredible degree. They determine who may or may not eat with whom, from whom one can receive food, the ritual that accompanies eating, and, most significantly, what foods may be eaten.

But in order to elaborate this, I first need to talk about the Hindu caste system, as, I need add, it existed on my "pin's head."

The area of India with which I am concerned is the Malnad, or hilly country, on the West Coast of South India. The economy of this region is primarily based upon two crops: arecanuts, which are sold into the national market and constitute a cash crop, and paddy, which is grown in sufficient quantities to meet the demands of the local economy. In addition, pepper, another cash crop, is grown in the arecanut gardens, and small plots of sugar cane are interspersed through the paddy fields. Although many other crops are grown—plantains, chilies, spices, fruits and vegetables of many kinds—these are distinctly of minor importance to the village economic system.

Villages, which are rather small, average 200-300 inhabitants. A typical village lies in a valley surrounded by forest. The upper end of the valley is transversed by an earthen dam, back of which is stored rain water which forms a small artificial lake. Rainfall, concentrated in a three to four month period, is generally sufficient to supply the needed irrigation water for the full year. Just below the reservoir lie the arecanut gardens, green, lush and damp. These gardens are almost never less than 10 acres, and often run as large as 70-80 acres. Below the arecanut gardens lie the paddy fields, often several hundred acres in extent. The lower paddy fields can be irrigated if necessary, but those along the side, on higher ground, depend entirely upon rain. The yield from these marginal lands is somewhat precarious, depending upon the amount and distribution of rain during the year.

The society in this rural economy is segmented into some two dozen hierarchically arranged castes, which tend to fall into one of three major groupings. The bottom of the hierarchy is composed of several Untouchable castes, who are primarily landless agricultural laborers who work for the owners of the arecanut gardens. Above these are a large number of Sudra castes, some of which are artisans,

e.g., blacksmiths, goldsmiths, potters, washermen and barbers, but the majority of which are agriculturalists farming the paddy fields which they either own outright or lease from members of their own or a higher caste. The caste hierarchy is topped by one of several vegetarian castes, who are exclusive owners of the rich and productive arecanut gardens, and who often own a considerable amount of the village paddy lands. They either lease these to Sudra agriculturalists, or, less frequently, farm them with the help of Untouchable laborers. The caste most often found in this position is Havik Brahmins. We can use the term "dominant caste" to refer to the landowning group who are at the top of the local caste hierarchy, as they control the economic and political system, and form the numerically largest single caste. The fact that this dominant caste is Brahmin, whose traditional occupation is priestcraft, and who are extremely orthodox in their observances of Hindu customs, gives the region a unique flavor and helps account for its conservatism.

Villages are divided into three or more hamlets, according to caste affiliation. Several Sudra castes sometimes live together, but never in the hamlet of the dominant caste. Untouchables are never permitted to live with or adjacent to the hamlets of the Sudra castes.

Castes are discrete social units, internally united by a common political organization enforcing customary law, which varies from one caste to another. Castes are generally united by having a common occupation, or at least the tradition of one. Kinship ties never cut across caste boundaries—individuals marry only within their own caste.

The criteria by which castes are ranked includes occupations, religious observances, social customs and types of foods that are prescribed and proscribed for their members.

Beliefs about ritual cleaniness and ritual pollution are of dominant concern to Hindus, and form the basis for the classification of objects, values, customs and people into an ordered system of rank. For example, ritual pollution is transmitted by various objects—pottery is a better conductor of pollution than is copper, and copper a better conductor than gold. Therefore, castes who make objects of clay are lower in the caste hierarchy than those who make brass vessels, who in turn are lower than those whose occupation involves working in gold. In like manner, animals are graded according to relative degree of sacredness, with cows, Brahmins, cobras, and monkeys, in that order, at the top of the hierarchy. To kill any living creature is believed to be ritually defiling, but the more sacred the animal whose life is taken the greater is the amount of pollution, and, therefore, the lower the rank of the caste associated with taking its life. Thus, a worker in cow's leather is always an Untouchable, while an agriculturalist, who only inadvertently takes the life of insects while plowing his land, is following a higher status occupation. The really pure castes, Brahmins, do not intentionally take the life of any animal, and thus may not plow their own fields.

Concepts of sacredness also apply to a house. The kitchen is the most sacred, and most easily polluted, part of the house. Members of lower castes are almost never allowed in the kitchen of a higher caste household, although other parts of the house may not be so restricted. For fear of ritual contamination to self, members of a higher caste rarely enter a house belonging to a lower casteman. Thus, access to another's kitchen is dependent upon being of the same caste.

Caste rules specify with whom one may and may not eat. Generally, an individaul interdines freely only with members of his own caste. A member of a higher caste can under no circumstances accept food or water from a member of a lower

caste. However, a lower caste person may generally accept food from a higher caste individual. As the higher caste person would be defiled by dining with the lower casteman, this contact is restricted to the lesser ranking individual accepting food from, or being served by, the person of higher rank, and this contact itself is infrequent. Thus, knowledge about the dietary habits of one caste tend to be relatively restricted from another caste.

Eating is a private matter. Members of lower castes are never supposed to gaze upon members of higher castes while they are eating, and members of lower castes do their best to keep from being seen by members of other castes while eating. This custom is intimately related to two concepts. The first is ritual pollution. Under some circumstances contamination can be transmitted by sight or by a shadow, as well as by direct contact. The second is the belief in evil eye, the belief that some people have the power to cause harm to befall those whom they envy.

The types of food consumed and the manner in which they are prepared differ from caste to caste. In the simplest case, this is explained by economics. For instance, rice is the staple in this region of South India. Untouchables are sometimes unable to afford it and substitute millet a food source rejected by all who can obtain rice. Although milk and milk by-products are converted by all, only the more wealthy individuals can regularly afford them.

Each caste has its own recipes, often unknown to other castes. These special dishes act as a symbol of caste identification, and even if known to members of another caste, may be rejected on the grounds that their use would be an inappropriate affectation.

But ritual evaluation is of greater importance in determining which foods may be eaten by members of different castes. Castes are sharply differentiated according to whether or not they eat meat. Vegetarian castes are at the top of the hierarchy, and as, in this part of India, the highest castes also tend to be the most wealthy, there is a high correlation between economic class and ritual rank in the caste system. Fish and eggs are included under the category of meat. To eat no meat is indicative of high ritual status; to eat the flesh of the most sacred animal, the cow, is the most ritually defiling, and is indicative of the lowest ritual status. In between these extremes, various meats are ranked according to the amount of ritual defilement involved in their consumption.

Each caste specifies what foods may and may not be eaten by their members, and enforces these rules by sanctioning violators with excommunication from their caste. The ranking of meats, starting with those that are the least defiling, is as follows: eggs, fish, chickens, goats and sheep, pigs, monkeys, and finally water buffalo and cows. Thus a caste which allows its members to eat only eggs and fish is more pure than a caste which allows its members to eat chicken as well, and so on.

In addition to food restrictions based upon caste affiliation, there is variation in food practices according to the predisposition or orthodoxy of a family or individual. A member of a middle Sudra caste may choose not to eat certain foods, *e.g.*, mutton, even though there are no caste restrictions against his doing so. This act enhances the individual's personal prestige, but is irrelevant to the ranking of his caste in the hierarchy. But, as we shall see, it is quite within the realm of possibility for the whole caste to impose restrictions on the type of foods permissible to their members in the hope that this will raise the corporate status of their group.

A case in point, if we move back in time for thirty years, is the consumption of beef by Untouchables. One of the duties that fell upon the Untouchables

in a village was to remove dead cattle belonging to other castes. For performing this job they were paid in cash. They also skinned the animals and sold the rawhide in the market town. These two sources of money enabled them to purchase liquor for the whole caste hamlet, and the carcass supplied meat for a day or two of feasting. Although cattle were never intentionally slaughtered, the end of every beast was the pot. About thirty years ago the Untouchable caste council prohibited their members from removing these carcasses and from eating beef. Now a dead animal is dragged into the forest by its owner and his neighbors and finished off by dogs and vultures.

It is hard to estimate the importance beef had in the diet of Untouchables, but it is worth noting that they live at a bare subsistence level, and that meat in any form is extremely rare. Prohibiting the eating of beef, which previously was regarded as an occasion for a feast, was done as an attempt to raise the rank of their caste. This is one instance, by no means an isolated one, in which a desire to be socially mobile has changed the dietary habits of a caste. Hindu values against beef, and, incidentally, against water buffalo, are such that this source of food is now completely rejected by all castes in this area.

We can now see that rank in the caste system is related to food restrictions: the higher the caste rank, the more numerous and stringent are the food taboos. We can also generalize another way: food prohibitions are most all-encompassing in those castes which have the greatest ability to command foods considered desireable by all castes. (I should add that this generalization is by no means true for all of India.)

Let me now turn to the foods which are tabooed by Havik Brahmins, the highest ranking caste in the area, and the most wealthy. In addition to rejecting eggs and all meat, Brahmins do not drink any alcoholic beverages. Nearly all other castes drink either toddy, a naturally fermented juice obtained from a type of palm tree, or *sarai,* a liquor distilled from locally grown sugarcane. Brahmin diet is restricted to fruits, vegetables, grains and milk products. No fruits, most of which are relatively scarce, are prohibited. However, there are numerous vegetables which are proscribed to Brahmins or are felt to be undesirable foods. Mushrooms, which grow wild in the fields and forests, may not be eaten. Also any vegetables which in color resemble meat should not be eaten. These include beet roots, pumpkins, carrots, tomatoes and radishes. In addition to these, strong foods, such as onions and garlic, are felt to be inappropriate to Brahmanical status. Finally, potatoes are frequently rejected as being Englishman's food.

There are certain foods that are found in the diets of all castes. Arecanuts, along with betel leaves, lime and sometimes tobacco, are universally used. Certain forest products, notably jackfruit and bamboo shoots, are seasonally in abundance. The most commonly used vegetables are any of a number of types of gourds. Green chilies are an absolutely essential ingredient of every meal. Rice is the preferred staple for all castes. The villagers in this part of India frequently state that the minimal ingredients of a meal consist of "rice, salt and chilies."

The fact that the more wealthy castes do not eat certain foods increases their availability to lower castes. This is particularly true for foods that can be obtained by foraging, such as mushrooms and freshwater crabs. Lower castes catch fish from the streams and reservoirs, during some seasons, in fairly large quantities. Should members of the dominant caste desire these foods, they could, because of their political control of the village lands, restrict the gathering or catching of these items to themselves. In like manner, the fact that all meats are prohibited

to higher castes decreases the competition for them, thus lessening the pressure on the available supply.

Besides eggs and fish, there are now only two major sources of meat for those castes that eat it—chickens, and goats and sheep. I classify the latter together because the villagers do. Chickens are rarely killed simply for food—goats and sheep never. Instead, they are killed to propitiate minor deities and to pacify disease-causing spirits. The quality of animals so sacrificed varies according to wealth. For the festival to the major village deity, the smallpox goddess, a well-off hamlet composed of agricultural Sudras may sacrifice one animal per family, whereas in an Untouchable hamlet ten families may join together to purchase a goat or sheep. This differential is reflected in the way the supernatural "benefits." All castes who offer blood-sacrifice to the deity end up eating the animal itself, but whereas the Sudras give the blood to the goddess, the Untouchables collect and use this in their own cooking, offering the goddess merely the essence of the sacrificed creature.

Not only are foods classified according to their purity and strength, but also many foods are classified as containing properties referred to as "heating" or "chilling." These distinctions are of greatest importance during times of illness, and form a part of an allopathic medical system. Cooling foods, such as curds and fruits, should be eaten when fever is present; heating foods, such as clarified butter, spices and meat, when the patient has chills. This classification is extended to include types of illness not so readily associated with fever or chills, and a large number of foods. In one instance, when we offered vitamin pills to a neighbor, a woman pregnant with her thirteeth and fourteeth children (twins), and who complained of severe weakness and tiredness, they were returned after one dose with the explanation that they produced heat, and therefore were not appropriate to the occasion. Also when I once had a cold, several villagers instructed me to avoid oranges and grapefruit because they were chilling foods; in their conception chilies were more appropriate.

The introduction of new foods into this stratified society is fraught with difficulty. The foods consumed by the high castes often connote not only prestige, but also purity and wealth. Lower castes sometimes have the benefit of being given foods by higher castemen. Thus foods become visible and available for acceptance by lower castes. But it is the higher castes who are the most conservative about adding new foods to their diet, and who also have the economic resources that make it less necessary for them to accept any but traditional foods. To the extent that a new food is rejected by a high caste, it tends to be stigmatized as an item that imparts some degree of pollution to the consummer.

Villagers point out that within their memory two new foods have been introduced—coffee, always served with sugar and milk, has become a popular drink with those who can afford it, despite the fact that it is thought to be debilitating. Secondly, during the last World War, when rice was rationed, wheat was introduced. It was originally thought of as a necessary evil but is now fairly well accepted. Some Brahmin families pride themselves on their cosmopolitan ways by pointing out that they eat a wheat meal each week.

During the period in which these new items have been introduced, three meats—beef, pork and monkey—have been excluded, This has affected only the lowest castes, as other castes did not traditionally eat them. As the two new items, coffee and wheat, have not been, for reasons of expense, added to the diet of the lowest castes, we see the foods available to the

higher castes increasing, and those to the lower castes decreasing.

In conclusion, my theme has been that the general cultural setting in which a people find themselves is an important determinant of the foods they regard fit for "human" consumption. The choice of diet is related not only to available foods, but also to socio-cultural factors.

It is significant to note that the values towards food in this Hindu community exist in a setting which is not noted for its abundance of nutritious foods compared to its population density. It might be suggested that such an extreme interpretation of what constitutes edible materials can develop more easily in a highly stratified society, such as India, when different segments of the population eat different items. Thus, although some groups prohibit the consumption of many foods, and some groups are, for economic reasons, denied the consumption of other foods, the total available resources nevertheless tend to be fairly well exploited. Exceptions to this statement have already been noted.

Conclusions

There appears to be a rather wide range of foods, and combinations of foods, that will sustain life. Some foods apparently do this job more efficiently than do others. A nutritionist may give clues as to what dietary practices best serve the end of survival, health and longevity. However, such knowledge in itself does not necessarily change eating habits. Values other than nutrition may take precedence.

Modern scientific research is, at one level, making progress towards solving man's present food shortages, both by discovering foods that are edible but not eaten and ways to convert otherwise inedible products into nutritious foods.

However, the problem of inducing people to eat that to which they are not accustomed remains unsolved. The human animal is quite capable of starving, or at least remaining undernourished, in the midst of plenty. I have no doubt but that some South Indian Brahmins would prefer to starve than to eat meat.

One of the most significant research questions which we can ask about patterns of food consumption concerns the willingness of peoples to eat one food but not another. This question needs to be answered in order to shed light upon the more practical applied question of "how can we get people to change their dietary habits?"

Two approaches to this problem seem most likely. First, to study the socialization process of the child in order to determine why he rejects or accepts, likes or dislikes, certain foods from the large array which are offered to him. Secondly, to examine the cultural factors which define some nutritious substances as edible while other equally nutritious foods are rejected. In neither instance are we necessarily dealing with simple qualities such as taste, odor, color or texture—instead, we are asking questions about emotions, values, conceptions of what constitutes prestige, and about social structure.

The Rockefeller Foundation Program in the Agricultural Sciences[1]

L. M. ROBERTS[2]

There are valid reasons for man's anxiety about his food supply. To increase the productivity of agriculture in the world, especially in those areas where agriculture is still underdeveloped, is a challenge of great urgency. The agricultural program of The Rockefeller Foundation was designed with this objective in mind.

The agricultural program of the Foundation began in 1943 when the Mexican government and the Foundation inaugurated a cooperative effort initially implemented by a one-man mission. The Foundation has been concerned with problems of human welfare throughout the world since it was founded in 1913, and it had from the beginning given special emphasis to the improvement of public health. Since nutrition plays such a basic role in determining the level of public health, as well as the level of man's productivity and general well-being, it is not surprising that the officials of the Foundation became interested in agriculture as a means of improving nutrition.

The decision to embark on an agricultural improvement program was not taken hastily, however. As a preparatory step, The Rockefeller Foundation in 1941 asked three distinguished scientists to study the situation in Mexico to determine whether it would be desirable and feasible for the Foundation to undertake a program in that country; and if so, to recommend the type of work that should be attempted. This committee, made up of Dr. E. C. Stakman, Dr. Paul C. Mangelsdorf, and Dr. Richard Bradfield, reported that the opportunity was attractive for the Foundation to sponsor an operating program of agricultural research and training in cooperation with the Mexican government aimed at increasing the production of the basic food crops. Their recommendations also included certain guiding principles for the establishment of such a program.

The Mexican government promptly extended a cordial invitation to the Foundation and a formal agreement between them was signed in February, 1943, officially launching the cooperative program.

From the very modest start in Mexico 18 years ago the present agricultural program of the Foundation has developed. The pattern of cooperation developed in Mexico has since been extended to Colombia, Chile, and India and from it have evolved hemisphere-wide cooperative projects for the improvement of maize, wheat, and potatoes and a worldwide program of rice improvement. Although these cooperative programs are modest in terms of staff and financing, they have proved effective in contributing to the advancement of agriculture far beyond the boundaries of the host countries involved.

As in its earlier work in public health, the Foundation's activities in the agricultural sciences combine operating programs, awards to individuals for specialized training, and grants to institutions. I should perhaps explain that an operating program is one in which the Foundation takes an active part in administering

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research and training projects through resident staff members and makes direct contributions to their operating costs. Obviously, training awards and grants are valuable techniques in themselves, and the Foundation is using them in a number of countries where no operating programs exist, especially in Latin America, Asia, and Africa. It is the combination of these with an operating program, however, which best illustrates the Foundation's coordinated approach to improve research and education as basic steps toward increased agricultural productivity.

Since the Mexican program was the first operating program to be started and is the model on which the others have developed, I shall now focus attention on it to give a brief summary of its organization, operations, and some of its accomplishments.

The Mexican program was organized as an integral part of the Ministry of Agriculture, and to insure stability of organization and flexibility of operation, the Mexican government set up an Office of Special Studies with headquarters in Mexico City. As a joint dependency of the Ministry of Agriculture and The Rockefeller Foundation, and with semi-official status, the Office had a much greater degree of freedom of action than if it had operated strictly under official rules and regulations. The Ministry and the Foundation contributed to the operating costs of the Office, and also jointly provided the personnel from their own staffs to man the program. In addition, the Mexican government provided land, labor, office and laboratory space, and a portion of the machinery and supplies. The Office has now been absorbed into a consolidated research branch of the Ministry, as will be described later, but the essential features of the cooperative program continue as before.

From the beginning the program has had two primary functions. One is to conduct research directed toward increasing the quantity and quality of the basic food crops. The other is to train young agricultural scientists so that they can assume as rapidly as possible the responsibilities for continuing the development of the agricultural sciences and the improvement of agriculture in their country.

When Dr. J. G. Harrar arrived in Mexico in 1943 as the first director of the new venture, he spent the first few months traveling widely to get to know the country, the people, the agricultural institutions of all kinds, and the agricultural potential, problems, and needs. Although the Advisory Committee had set forth in its original report some broad principles and basic guidelines for the development and operation of the program, others had to be worked out in this initial stage by Dr. Harrar. As the program has grown, additional principles have evolved, but the fact that the original ones developed by Dr. Harrar and the committee members have provided the base on which the agricultural activities of the Foundation have been built testifies to their vision and imagination.

Corn, wheat, and beans were the first three crops chosen for investigation. The Foundation soon assigned other agricultural scientists to the program and projects were begun to produce better varieties of these crops by selection and breeding techniques, to improve the soils and cultural practices which would increase their yields, and to investigate and control pests and diseases that limit their production. The plant breeders, the soil scientists, the entomologists, and the pathologists worked as a team to improve the production of these crops, with excellent results. This spirit of interdisciplinary cooperation continued as the program grew and other crops were added for investigation and improvement. In addition to corn, wheat, and beans, the program now includes improvement projects on potatoes, vegetable crops, sorghums, soybeans, rice, barley, and for-

age grasses and legumes. In 1955 a poultry specialist was added to the staff and soon afterwards a veterinarian was also added to work in animal pathology, emphasizing at first poultry diseases. Sections on agricultural economics and agricultural information have also been inaugurated, and a reference library has provided a necessary service practically from the beginning of the program.

In conducting the research projects, the program collaborates closely with the Ministry of Agriculture in developing and operating experiment stations. The cooperative program has had responsibility for developing a chain of four regional stations tied into the Central Research Center located on land of the National College of Agriculture at Chapingo, near Mexico City. The program also collaborates with different state governments and agricultural colleges in the establishment and operation of other experiment stations, and in addition experimental plantings are made on a large number of private farms.

The research and training activities developed hand-in-hand from the very beginning of the cooperative program. During the past 18 years over 500 young Mexican agricultural scientists have received in-service training in the cooperative program They have been commissioned by the Ministry of Agriculture to serve internships for periods of a year or more under the direction of Foundation staff members. Practically all the former interns have continued in some phase of agricultural development work, and many now have important positions in one of the official or semi-official organizations involved in teaching, research, extension, and seed increase and distribution.

The outstanding trainees are awarded Foundation fellowships to take postgraduate studies in the United States, where to date 80 have earned a Master's degree and 18 have completed the requirements for the Ph.D. degree. These young scientists who have trained in the cooperative program and have had advanced training abroad are providing most of the leadership in professional agriculture today in Mexico.

The Mexican program also serves as an international training center. More than 75 young agricultural scientists from other countries of Latin America have spent a year as trainees working and studying side by side with the Mexican interns. These men have been selected under the Foundation's scholarship plan from candidates who hold responsible positions in agricultural institutions in the different countries, and on completion of the training in Mexico, they have returned to their homelands to apply their new knowledge and skills to local problems. In addition, several hundred distinguished agricultural scientists from many parts of the world, some on Foundation travel grants and many on their own, have visited the program for shorter periods of time.

Although research and training are its two primary functions, the operating program makes important contributions to agricultural development in Mexico through several collateral activities. It collaborates closely with the colleges of agriculture, the federal and state extension services, and the agencies responsible for the increase and distribution of improved seeds. Perhaps the most valuable contribution that the program makes to these and other allied institutions is to provide them with qualified personnel through its training activity. Fellowships and travel grants are also used to help train a significant number of their staff members.

Assistance to the four colleges of agriculture in Mexico is given a high priority by the program. Over the years grants for increasing and strengthening faculties and for equipment and libraries have been made to these colleges by the Foundation.

Two years ago a Graduate School was

inaugurated at the National College of Agricuture at Chapingo. Several of the Foundation's staff were invited to help plan and develop this school and some have been given honorary professorships to enable them to participate in its teaching and research activities. Graduate students from several countries in Latin America are already enrolled. Since it is no longer advisable or feasible to send all of the qualified young agricultural scientists in Latin America to the United States for advanced training, the Foundation is especially interested in the new Graduate School and has recently made a substantial grant to assist further in its development.

The program helps to promote extension work in Mexico in several ways. It has had for several years an information service whose function is to put research results into terms which can be easily conveyed to the farmers by the extension agents. The information is adapted for dissemination through all the principal media—bulletins, circulars, newspapers, radio, televison, and movies. Although the cooperative program is not directly involved in extension, many of its research activities serve as demonstrations for the public, especially the numerous regional adaptation trials made on private farms. In addition, each experiment station has one or more field days each year for farmers, and it is not uncommon for more than a thousand people to attend one of these.

In 1952 the State of Mexico launched the first state extension service in Mexico. In 1953 the Ministry of Agriculture reorganized and enlarged the National Extension Service. The cooperative program has provided trained personnel, improved varieties, information, and technical consultation to these. In addition, the Foundation has supported them through grants to provide equipment and visual aids.

Benefits of the research results are also extended to the farmers through the work of the agencies within the general structure of the Ministry of Agriculture responsible for increasing and distributing the seeds of improved varieties. The program furnishes these agencies with basic seed stocks of new varieties, counsels them on technical problems, and helps to train the personnel for their staffs.

Time will not permit a comprehensive review of the principal results and benefits that have come from the Mexican program, so only a few general comments will be made about these. When the program started, Mexico imported over 50 per cent of the wheat that was consumed annually and usually had to import some of the corn it needed. Now Mexico produces all it requires of both crops even though the population has increased approximately 13 million or 60 per cent in the past 18 years. The Food and Agriculture Organization of the United Nations recently reported that Mexico has had a 7 per cent annual increase in agricultural production during the past ten years, incidentally among the highest in the world, while the population was growing at an annual rate of 3 per cent, also one of the highest anywhere. Such an achievement is due, of course, to contributory factors from many different sources, but the improved varieties and better farming methods, and the significant number of trained agronomists developed by the cooperative program, have had an important role in making it possible.

In 1960 the officials of the Ministry and the Foundation mutually decided that the point had been reached at which it would be desirable to place more of the responsibilities for the direction, administration, and execution of the research program on the Mexican scientists who have been trained in considerable numbers to shoulder them. As a consequence, a new organization, the National Institute of Agricultural Research, has been established recently in the Ministry to consolidate all

federal agricultural research in a single administrative branch. With the creation of this institute, the Office of Special Studies has been discontinued and its functions are being integrated with those of the new organization. The staff of the Foundation will now retire more into the background as regards administrative matters and will gradually withdraw to advisory roles in the research projects. This move is an important milestone along the road to the ultimate goal, eventual withdrawal, set for the cooperative program when it began in 1943.

Four new international programs, all less than two years old, have evolved from the operating programs.

One is the inter-American corn improvement project. Since 1954 the Foundation has sponsored a regional corn improvement project in Central America. Its success prompted the next step, to extend this type of assistance to all of the countries of the Western Hemisphere. The Foundation provides a staff member to coordinate the activities which basically consist of regional cooperative trials, exchange of genetic stocks and information between the cooperators in the different countries, regional meetings of the corn breeders, and training programs. The improved varieties and lines from the Mexican and Colombian programs are made freely available to the cooperators. The vast reservoir of indigenous races of maize in the corn germ plasm banks in Mexico and Colombia are being studied and evaluated on an international scale with the help of some of the leading United States scientists and the corn breeders of Latin America.

The international wheat improvement project is operating along the same general lines throughout the Americas and in addition is collaborating with FAO of the United Nations in wheat improvement in the Near and Middle East. The project already has uniform yield experiments planted in 15 different countries. At the present time seven young wheat breeders from the Near and Middle East are training in the operating program in Mexico. The inter-American potato improvement project was launched within the past few months.

The International Rice Research Institute is in the initial stage of development at Los Baños in the Philippines. The Ford Foundation has appropriated approximately $7,000,000 for buildings and equipment, the College of Agriculture of the Philippines provided the land, and The Rockefeller Foundation is providing technical direction and administration of the Institute and funds for operating expenses. The Institute is governed by an autonomous Board of Directors composed mainly of representatives from countries of the "rice bowl" of Southeast Asia. Both basic and applied research will be conducted on the rice plant and on all of the factors having to do with its yield and quality.

The use of fellowships, scholarships, and travel grants to complement the training activities in the operating programs has been described. Similar awards are also employed in practically all the countries of Latin America, several in the Orient, and more recently in some of the African nations. Approximately 500 fellowships have been awarded to agricultural scientists from some 50 countries, and over 350 scholarships have been given to representatives of 25 countries since the beginning of the program. The travel grant is another technique used to broaden the experience of mature, senior scientists. These are not limited to individuals from underdeveloped countries as are the fellowships and scholarships.

A grants program to support research and education is the third major area of activity in the Foundation's program in the agricultural sciences. The grants to institutions in the underdeveloped areas are primarily for developmental purposes, while those in the United States and Eu-

rope support very fundamental types of research.

Eighteen years of experience have shown that the pattern of activities of the Foundation's agricultural program is a useful one in helping to improve the world's agriculture. The program is relatively small both in staff and finances. The staff in Mexico at its maximum size numbered only 18. At present fewer than 50 staff members work in the whole program. In 1960 the total budget for Agricultural Sciences was approximately $6,700,000. Limitation in size has been an advantage for it has tended to stimulate an intensification of effort with emphasis on quality. In this regard, the care which has gone into the selection of the field staff must be mentioned. This has been a major factor in determining the success of the program. The individuals chosen to work in a technical assistance program must have not only technical competence but also a broad spectrum of personal qualities that will permit them to work effectively and happily in a foreign environment. The fact that positions with the Foundation offer permanent career opportunities with reasonable assurances of stability, advancement, and agreeable conditions for family life makes it possible to attract individuals of high caliber.

The program has had other important advantages. From the beginning it has operated under a stable policy backed by stable support. The program in Mexico, and other operating programs likewise, was started with the understanding that it would be self-liquidating but also with the equally important understanding that a rather long and indefinite period would be required before the Foundation would be able to withdraw completely from the task. The Foundation has gladly given increasing support to this operation over the past 18 years as it has grown in response to opportunities, keeping in sight all the while the ultimate goal of eventual withdrawal.

The program has had the good fortune of receiving warm acceptance, understanding, and support from government officials, collaborating scientists, and the general public in the different countries where it has activities. This is very important, for technical assistance can be effective only where there is a strong local desire to receive and make use of it. Also the collaboration which the program has received from institutions in the United States, especially the United States Department of Agriculture, the different colleges and universities, and the National Research Council, has been of great assistance.

Under the most favorable circumstances the process of extending technical knowledge and modernizing agriculture in the underdeveloped areas of the world is a relatively slow one in comparison with the present rate of increase in population. The social, economic, and political problems involved are numerous and complex and the progress on any single front such as agriculture cannot proceed much faster than the rate of general advance on the other closely related fronts such as general education, total economic productivity, health, political stability, and general social progress.

Progress in Biochemical Engineering Broadens Our Choice of Crop Plants[1]

N. W. PIRIE[2]

Primitive man, like many animals, separated the edible from the inedible and the useful from the useless parts of the plants and animals that he gathered or hunted. This is easy so long as the parts to be separated are large; a coconut shell or a bone is simple to get off or out. As the scale of construction gets smaller, problems arise, but by 3000 B.C. or thereabouts some of them had been solved and by Roman times technology was competent to separate a fine flour from chaff and bran, oil from olives, and wine from skins and lees. After this there was little advance in the technique of biochemical engineering until the present century, but even now little effort is put into attempts to apply modern knowledge and skills to the extraction of further useful materials from existing crops, nor into the search for such materials in a new range of plants. If this were done, it would be possible to approach agriculture in a novel way; instead of making up our minds what we want to grow and then trying to grow these crops in increasingly improbable parts of the world, we will find out what each region grows most efficiently and will then see what use can be made of that.

This symposium is welcome evidence that the world's need for more food is now generally recognized. It is less generally recognized that the need for protein is greater than that for the other components of a diet and that it will be the most difficult need to satisfy. For this reason, and also because my own work is concerned mainly with protein extraction, this article will deal mainly with protein supplies, but similar principles apply generally.

Preparation of Leaf Extracts

The most common sources of biological material are wood, starchy tubers or piths, and seeds. There are practical and historical reasons for this selectivity, but the potential yield of leaves from any land that can be cultivated is greater than the yield of these other products, for they are all derived secondarily from leaves by translocation. More attention should therefore be given to the possibility of using leaves directly in spite of their perishability and inconvenient texture. When confronted with the latter difficulty the engineer tends to think of two alternatives: drying so that the disintegrated material can be blown out of a mill, or wetting so that the slurry will flow out of it. Drying is an excellent step in making hay or tea or as a prelude to the extraction of such things as alkaloids. Sullivan (25) extracted some of the protein from ground dried leaves with dilute alkali, but drying is not a satisfactory first step in extracting proteins and other macromolecules because, on drying, these materials get denatured to a large extent or in other ways become attached irreversibly to the fiber.

Ereky (11) proposed that leaves should be ground while suspended in water, and this course has had recent advocates (1); but it is inconvenient to have to handle a large volume of dilute extract. It seems

[1] Presented at Second Annual Symposium of The Society for Economic Botany: *Integrated Research in Economic Botany II. Nutrition for an expanding world population.* Massachusetts Institute of Technology, Cambridge, Mass., May 14, 1961.

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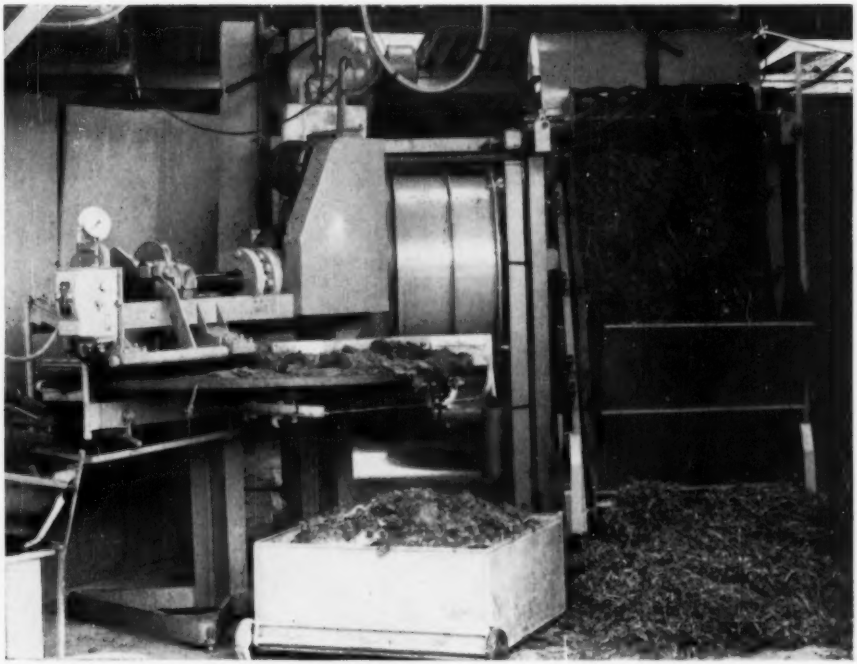

Fig. 1. General arrangement of the unit for extracting protein from leaves. The crop in the hopper on the right is carried up the elevator at a uniform and controlled rate and falls into the pulper. This is the horizontal drum in the center, and from this the pulp flies out under a cowl and on to the circular table of the press. The platen of the press is shown in the "down" position. As the cams shown on the left rotate, it is lifted, and this movement (by a link mechanism in the center that does not show in the photograph) forces the table around and so brings fresh pulp around under the platen ready for the next stroke. The spent fiber is scraped off by a weighted wooden board while the juice runs into the strainer on the extreme left.

preferable therefore to use on a large scale the method used to extract protein in the laboratory (22, 4) and pulp the fresh leaf, only adding water when the leaves are exceptionally dry.

After much preliminary work with screw expellers, which act as disintegrators only because of their relative inefficiency as presses, and rollers, which do not allow the liberated juice sufficient time to flow away, the principle of the hammer mill was chosen as the most practical for large-scale disintegration (17). Leaves containing 80-90% of water yield an intractable dough; it was therefore necessary to modify existing hammer mills to make one that could not choke. This is fed axially at one end and discharges tangentially at the other. There is no screen inside; what goes in at one end comes out at the other, whether it has been satisfactorily pulped or not. Some skill is therefore needed to ensure that the speed of the pulper, and the extent to which the passage of the charge through it is obstructed, are suitably matched to the texture of the crop. The detailed arrangements for achieving the right amount of disintegration are slowly evolving; their present state has recently been described (8).

The range of devices used to separate

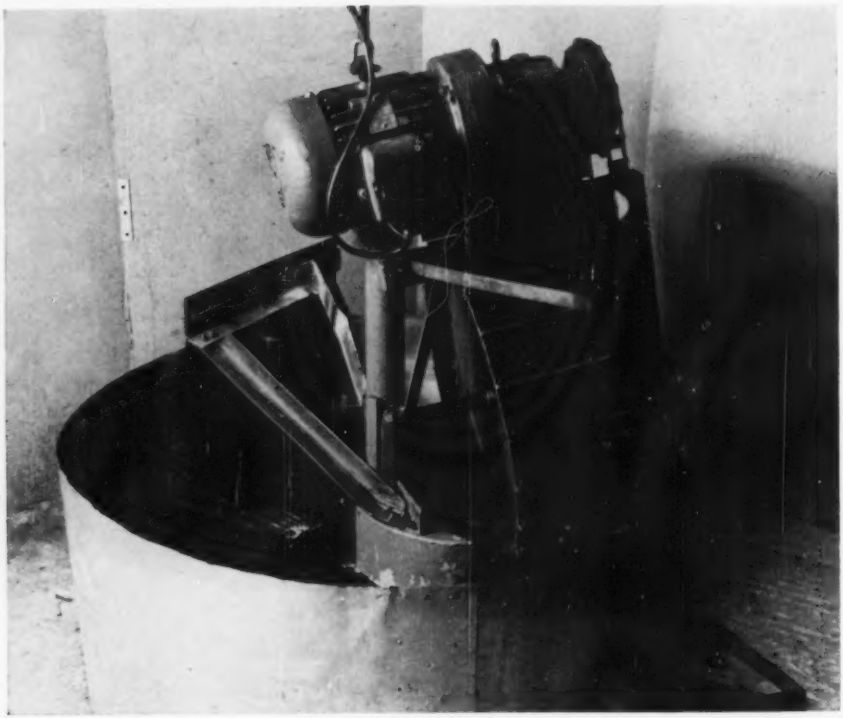

Fig. 2. Device for extracting juice from 100-200 lb. batches of leaf. The ribbed roller is driven by sprocket and chain so that is moves around on the slotted bed; two scrapers keep the charge in its track. Pulping takes place because of the twisting action of a cylinder forced to roll around a circular track and also because it only moves forward by trying to climb up the mass of leaf on the bed. The juice runs through the slots and the perforated center piece. The motor (which could of course be replaced by a different type of drive) and rotor are mounted on a frame that is free to move up and down on a central pillar and accommodate a charge of variable thickness.

solids from liquids—gravity, suction, coil and drum filters, screw expellers, hydraulic presses and so on—suggests that each particular type of material presents a special problem. The principles involved in separating fluid from a fibrous pulp have been discussed elsewhere (20). There is little advantage in exposing a leaf pulp to more than 100 lb. per sq. in., but the pressure must be maintained for long enough to let the fluid run away. Because much of the protein that we are trying to extract is present as chloroplast fragments, it is advantageous to use as thin a layer of pulp as possible; otherwise the protein is retained by a tightly packed fibrous bed. An early press meeting these requirements consisted of a set of perforated plates, hinged together to form a belt, passing intermittently under a hydraulic ram. This has now been simplified (8). A rigid perforated horizontal annulus passes intermittently under a ram which is forced down by cams. The usual cycle allows six second pressing time and one to two seconds for the automatic rotation of the annulus through the angle necessary to bring a fresh part of

the charge under the ram. The times can be varied to suit any special conditions or texture of the pulp being pressed. When fed with material containing 80-90% of water, the present model can handle one ton an hour and decreases the water content 60-70%; it is driven by a two hp. motor. The press was designed to get a protein-rich juice from leaf pulp, but it may well have wider application than this and it deserves trial on such materials as disintegrated sugar cane and oil seed meals. Figure 1 shows the general arrangement of the pulper and press for large-scale continuous running. Figure 2 shows a smaller unit that is still in the development stage; it extracts juice from 100-200 lb. batches of leaf in one operation.

When a macromolecule is being extracted it is essential to break open the cells by cutting or rubbing; the latter process is probably the more important in the pulper described above, for there is satisfactory liberation of protein even when the pulp still contains clearly visible fibers and fragments of leaf. When substances with small molecular weight are being extracted, the cells can with advantage be left intact so that the cell wall retains macromolecules (19), but the systems controlling the osmotic pressure of the cell must first be destroyed. It is hardly feasible to get water, let alone solutes, out of most cells by pressure alone. Neglect of this general physiological point has led to many fruitless attempts to lower the water content of tissues by pressing them. Such attempts as seem to have been successful, the pressing of "water" from forage in Florida to lower the costs of drying for example (21), probably depend on the cells being damaged by shearing in the press. There will then be loss of protein, because of the shear, approximately proportionate to the loss of water. An extensive range of poisons, often referred to as plasmolysing agents, can be used to destroy osmotic control, or frost sensitive tissues can be frozen. Both methods are commonly used in the laboratory, but on a large scale it is more convenient to heat the tissue momentarily to some suitable temperature in the range 50-80°C. This is commonly done, though apparently the reason is not always understood, as a prelude to expelling oil from seeds; the practice should be extended. Thus, it is likely that oil could be economically pressed from coconut without the tedious and expensive process of drying to make copra if the meat were first heated, and lush vegetation could be much more economically dried if it were first heated and pressed to remove ⅔ to ¾ of the water. Sugars, amides, etc. would be lost in the liquor from leaves; but even if this were thrown away, the loss would be outweighed by the saving in drying costs.

Leaf Protein

The isolation of useful products from leaf extracts need involve only the standard processes of industrial chemistry. If protein is the primary objective, it must be separated from the water soluble components of the leaf; in the laboratory this has generally been done by acidification, for almost all the leaf proteins are precipitated at about pH 4. On a large scale it is more convenient to coagulate it by heating to 70-80° (15). This irreversibly denatures the protein so that it is no longer practical to get a water soluble protein; this is a pity, but acid precipitation is not for this reason to be preferred to heat coagulation because most of the leaf proteins are so sensitive to any manipulation that they quickly become largely insoluble. The heated coagulum, unlike that made with acid or salt, is dense and easily collected on a filter. Regardless of the method used to make it, it contains chloroplast fragments and so carries with it chlorophyll and between 5 and 30% of lipid. Some fractionation is possible before coagulation. Thus with many leaf species the chloroplast frag-

ments can be removed by high speed centrifugation. They are precipitated by lower concentrations of salts than some of the other proteins; and, as Rouelle (22) observed, they are more easily coagulated by heat. By judicious use of these processes, a dark green protein fraction and a smaller pale fraction can be made.

Leaf lipids are a complex mixture of fats (mainly highly unsaturated), waxes, carotenoids, pigments, etc. The main industrial use at present is as a chlorophyll source; but, as in other regions of industrial chemistry, if a supply were readily available, other uses would no doubt be found. The amount of nucleic acid in the protein depends on the details of the extraction procedure because, although leaves are a rich source of ribonucleic acid (16), they are also a source of ribonuclease (12) so that the amount of nucleic acid that accompanies the protein coagulum is greatly diminished when coagulation is delayed (23).

The object of this work is the production of a human food; leaf protein must therefore be made in a form that is both palatable and nutritious. The dark green appearance raises some difficulties in presentation, but we find that people quickly become accustomed to it and that in the earlier stages of its use the color can be satisfactorily masked by encasing the protein as in ravioli (14). Some preliminary human feeding experiments (7) give the protein a slightly lower value than milk protein, as would be expected; thorough experiments on pigs (2, 10) and other animals (9) give it a value as good as, or better than, fish-meal. We have demonstrated therefore that this protein can be made and that it is worth making.

Leaf Components of Low Molecular Weight

The water soluble components of the leaf vary with maturity and from species to species. The liquor that runs away from a protein coagulum therefore deserves very much more attention than it has yet had. The most obvious use is as a culture medium for micro-organisms because it contains sugars, amino acids and peptides, amides, nucleotides and their breakdown products, and various vitamins. Another possibility that deserves serious attention it that leaf protein production could be combined with the production of some other leaf component such as a drug or dye. This is an unfashionable point of view It is generally assumed that synthetic chemistry will gradually engulf all the industries that now depend on the extraction of substances from tissues or fermentation fluids, that this will be a step forward, and that, although we may continue to make substances such as ethanol by biochemical processes for sentimental reasons, such processes will be ousted generally. This attitude of mind comes about, not because synthesis has any intrinsic advantages over extraction, but because synthesis is part of an up-to-date technology that is striving to be efficient and to do things in the most economical and productive way. When modern technology comes into competition with a traditional peasant industry, it is not surprising that it prevails; that is why we have science. The contest is only valid when it is between synthesis and an extraction industry that has also been the subject of organized biochemical research. The present position with amino acids, antibiotics, and vitamins shows that it is not possible to generalize about the results of such contests; sometimes biochemistry and sometimes synthetic chemistry is the better.

We may pursue this argument, in a speculative way, with indigo as an example. Its precursor, indican glucoside, occurs in a great many different plant species of which *Indigofera* in India and *Isatis* in Britain are the best known. Woad manufacture from the latter continued into this century with slight technological improvements and a little

mechanization but with no research on the basic processes involved in crushing and fermenting the leaf. The methods were so crude that "to stink like a woad worker" was a common expletive. It is not surprising that the workers at any rate preferred synthesis. No attempt has been made to prepare protein from the leaves of any of the indigo-yielding plants, but it is reasonable to assume that at least one would be satisfactory and that the liquor running away from the protein coagulum would, if treated suitably, deposit indigo, which is extremely insoluble and could easily be recovered. Indigo is still an important dyestuff; alizarin has been to a large extent replaced by other red dyes, but it has merits and is present in madder and many other plants so that it also is a possible by-product.

Leaves, eaten directly, can contribute several grams of protein a day to a diet, but by tradition they are generally valued for more purely medical reasons. Their mineral content need not delay us—minerals are easily supplied in other ways—but leaves are useful sources of some vitamins. The possibilty of isolating ascorbic acid from them has therefore been explored; so far they have proved a less promising source than green walnuts, but the separation could become economic if the extract containing it were a by-product. Similarly, vitamin A and carotene are so plentiful in the fish oils that little effort has been put into their isolation from plants. This neglect is not necessarily justified.

There is no need to emphasize the importance of leaves, and therefore of the by-products from protein manufacture, as sources of alkaloids. Interest has recently been shown in the presence in them of serotonin (6), oestrogenic substances, and steroids (13). Leaves are components of so many spices used in food preservation, and of salves used in primitive medicine, that an interest in their bactericidal and bacteriostatic components is a natural consequence of the growth of the antibiotics industry. A recent review (24) ran to 100 pages with 200 references. Many thousand species have been tested, and the search still goes on, though for practical reasons not on the extensive scale of the search for antibiotic production by micro-organisms. There is, however, no reason to think either that antibiotic production is the prerogative of the lower plants or that the techniques needed to isolate them from higher plant extracts would differ significantly from those in general use. Nevertheless, no antibiotic made from leaves has as yet achieved commercial success.

The conclusion to be drawn from the last four paragraphs is that there are abundant possible uses for the low molecular weight components of leaves but that a great deal of laboratory research is called for before these potentialities will be turned into biochemical engineering actualities. In this connection it is well to bear in mind the dramatic recent improvements in our methods for separating complex mixtures by the use of molecular sieves and ion exchange materials.

Fibrous Residue from Leaves

When leaves normally used as fodder are being extracted, the residue can obviously be used as fodder. Because protein has been extracted it will be less nutritious than the starting material, but the products we have worked with contain 1.5-2.0% N. They can be ensiled and for the reasons already discussed are economical to dry. It is to be expected that various leaves, not normally palatable to stock, will give a palatable residue because highly flavored or toxic components are removed during the extraction. Some other possible uses are worth mentioning although no sustained work has been done on any of them.

Wood pulp is so plentiful and cheap that there is little incentive to look among other vegetable residues for sources of

cellulose, and if such a search were being made it would be wise to concentrate on mature tissues with little protein and other contaminants that have to be removed from cellulose before it can be used. It is possible, however, that the residual, firmly attached and uniformly distributed, protein in a leaf fiber residue would be useful if the residue were being used as a filler for plastics of the protein-formaldehyde type, and that the leaf protein could replace some of the casein normally used in them.

Finally the residue is a potential substrate for at least two types of fermentation. Unhydrated cellulose, cotton and filterpaper for example, needs treatment with a "swelling agent" before it is readily attacked by the cellulases and this may in part explain (18) the general neglect of this group of enzymes. There may at the moment be no shortage of molasses and other similar sources of fermentable sugars, but the attention given to techniques for hydrolyzing wood pulp with acid suggests that other sources will be welcome in the future. The digestion of leaf residues by bacterial or fungal cellulases is therefore an obvious possibility. The moist, disintegrated state of the residue make it a very suitable substrate for methane fermentation if that aspect of biochemical engineering were ever to be taken seriously. At present methane is generally looked on as a by-product, and the primary object of the fermentation of sewage or town refuse is a simplification of the disposal of the residue and an improvement in the local amenities. Several organisms are known that can make methane from simple substrates (3), but the nature of the mixed culture that is needed when cellulose and other complex molecules are the starting material is not known. When a new fermentation is being started, little attempt is made to seed it with an effective mixture; nature is allowed to take its course. Not unexpectedly results both on farms and sewage works are variable, and this leads to some hesitation about starting fermentations in a new environment. This was at one time also the position with cheese-making before the need for cleanliness and control were recognized.

Methane fermentation is a subject that would repay much fuller investigation and, when it is investigated, some attention should be given to the possibility of getting products more complex than methane. These should retain the merit methane has of being insoluble in water so that they separate automatically from the fermentation fluid and do not need, like alcohol or acetone, to be recovered by distillation; but they should have the extra merit of being liquid at room temperature so that they do not have to be stored in insulated or high pressure tanks. Micro-organisms, plants and animals all contain enzyme systems able to build up water-insoluble molecules (terpenes, rubber, essential oils, and various fats and waxes) from glucose. There is no obvious reason why these faculties should not be exploited to make a more convenient fuel than methane.

Sources of Plant Material

Work along all these lines can start with existing crops and wastes. The wastes offer particularly attractive possibilities. Thus in Britain the vines from canning and freezing peas are a useful protein source, and there are similar wastes overseas, not only from food crops but also from fibers such as jute and ramie. Wild plants and weeds are not a promising source because, on any land from which they can be harvested, they grow only as a result of some inadequacy in the farming technique. Water plants are more promising; we have extracted protein from the mixed flora of Hertfordshire streams, and experiment is called for on such plants as papyrus, water hyacinth, *Salvinia*, and some of the lilies. Besides being potential protein sources their removal would improve the amenities in many areas. In special cir-

cumstances weeds and wastes could be the sole raw material, but as a rule special crops would have to be used for at least part of the time. This raises two related questions; what crop would be grown and what land would it be used for?

Existing crops have been selected for many reasons; but because the protein content of their leaves is not an important one, it is unlikely that many of them will be ideally suited to our purpose. It may be worth while framing specifications for the ideal plant to meet biochemical engineering requirements. The guiding principle is that all parts of the plant should be useful. It should therefore have an edible tuber or rizome; a stem containing a useful fiber; leaves from which the protein can be readily extracted; a dye, alkaloid, antibiotic, or similar material in the sap; and a fruit or nut. Such a plant will not be found immediately, but there are a third of a million to choose among and breed from.

Cultural qualities are not the province of the biochemical engineer, but they may be mentioned so as to make the specification complete. It is convenient to use a legume and so, at least in part, avoid the need for nitrogenous fertilizers. Under British conditions a winter-hardy crop that can be cut regularly is desirable so as to maintain continuous green cover and make full use of what light is available. The ability to compete with weeds is valuable, but it may not be compatible with the growth habit generally associated with a fiber plant if this is a perennial or at least is to be harvested several times. As evidence increases, other requirements will be added to the specification. We cannot expect all these requirements to be met, but it is well to be clear about what is wanted.

The simplest course would be to grow the new crop on land that is already in cultivation, as an alternative to the crops to which that land is now dedicated. There are two main arguments for doing this. First, by harvesting leaves rather than following the techniques of conventional agriculture, a greater yield of nutritionally more valuable material can be won in a given time. The element of time underlies the second argument. Advocates of factory production of the main foodstuffs stress that in this way food production can be to some extent protected from floods, droughts, disease and other catastrophes. This protection is partly achieved when the growing period is shortened as it is when a plant is harvested in the vegetative state.

These arguments may not be generally accepted; alternative sites that do not compete with conventional agriculture should therefore also be considered. In countries with a long established and well organized agriculture waste land will not make a serious contribution; it is only uncultivated because of gross infertility or because it is difficult to get an implement over it. Tropical rain forest is in a different position. This is often left as forest partly because of the value of the timber and partly because erosion is a serious risk after felling. The possibilities of growing leaf-protein crops as an undercover should therefore be explored. There is already some experience to be called on in temperate orchards and tropical cocoa and rubber plantations. Byers (5) in Ghana found several shade-tolerant species from which protein extraction was satisfactory, but much more work on this aspect of the problem is needed.

The pace of further development depends on the realization that there is now a large unsatisfied need for protein and that leaf protein is a means of satisfying part of it. It also depends on botanical imagination being able to see that some of the uncultivated wild plants have potentialities as useful crop plants. The crops on which we depend for nearly the whole of our food were selected by primitive man in the light of his primitive technique. Technique is now improving, and

this should broaden the basis of our selection.

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Folk Uses and Commercial Exploitation of Aloe Leaf Pulp[1]

JULIA F. MORTON[2]

Several species of Aloe are cultivated in the tropics for their subepidermal yellow latex which, on evaporation, becomes the well known cathartic, "bitter aloes." Little has been written of the folk uses of the translucent parenchyma of the succulent leaves as a soothing, astringent, and healing poultice for skin diseases, wounds, burns and eye afflictions, and as a potion for various internal ailments. There is a small industry in Florida, based originally on the marketing of the fresh leaves and, subsequently, on the utilization of the pulp in ointments, cosmetic creams, lotions, shampoos and sundry other products.

In the Liliaceae there are nearly 200 species of *Aloe*, all succulent plants with fleshy, tapering, spiny-margined leaves arranged in a rosette or spiral. Some species appear almost stemless; others have stalks up to 20 feet tall. The majority are indigenous to South Africa. Many others are native to the areas bordering the Red Sea and the Mediterranean. More than seventeen species (28) have been cultivated in the tropics for the bitter yellow latex (turning red on exposure) drained from the longitudinal cells immediately beneath the leaf epidermis and which, after evaporation, becomes the cathartic, "bitter aloes," of the drug trade. Its use dates from the 4th Century B.C. (43). The principal sources are *A. perryi* Baker, *A. ferox* Mill. and *A. barbadensis* Mill. (syn. *A. vera* Tourn. ex Linn.) Fig. 1. The history and culture of these and less important species, as well as the harvesting, processing, chemistry and pharmaceutical aspects of the aloetic latex, are well recorded (33, 43, 64).

Prior to the 1930's little attention had been given to the folk uses of the translucent, mucilaginous "pulp" or fleshy parenchyma of the leaves. The pulp was generally dismissed in medical circles as pharmacologically inactive (35). Nevertheless, this pulp, alone or with other portions of the leaf, has been applied as a folk remedy for various external and internal maladies of humans and domestic animals and for sundry other practical purposes.

Hunters in the Congo are reported to rub their bodies with the astringent substance to reduce perspiration and thereby eliminate the "human scent," thus confounding their prey (22). In South Africa natives split the leaves of *A. saponaria* Haw. and lay the fleshy surface on wounds. The clear pulp and the yellow latex of this species and of *A. latifolia* Haw. are used to treat ringworm. Venereal sores are washed with a decoction of the leaves of *A. ferox* (72).

When there is an epidemic of colds, the Sutos require all the people of a village to bathe publicly in an infusion of *A. latifolia*. The pulp of this species is used on boils, sores, and infected and inflamed wounds. The leaves of *A. macracantha* Bkr., with spines removed, are crushed and steeped in water, the infusion being taken as an intestinal flush following a purgative. The leaves of *A. variegata* Linn. are infused in brandy and the liquor taken to relieve hemorrhoids. Various African tribes apply the fresh pulp of *A. ferox* for chronic conjunctivitis and other eye ailments (72). In India Drury states that the pulp of *A. barbadensis* is washed

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Fig. 1. Mediterranean aloe (*Aloe barbadensis* Mill.). The parent plant, tallest and slightly off-center in the clump, approx. eight years old. The suckers may be transplanted when 6 or 8 inches tall and will have full-grown, marketable leaves in 3 years.

SPECIES DESCRIPTION OF MEDITERRANEAN ALOE, *Aloe barbadensis* Mill. (SYN. *A. vera* TOURN. EX LINN.)

Succulent plants of the family Liliaceae. Stems stout (1-1 ½ feet tall in about ten years), supporting a close rosette of fleshy, swordlike, upturned leaves, the base of each clasping the stem. Mature leaves gray-green, white at the base, and sometimes reddish-brown in full sun; 20-22 inches long, 3 ½-4 inches wide at the base, tapering to a slender tip, flat on the upper surface, rounded on lower, ¾-1 inch thick near the base, ¼ inch or less at the tip; margins spiny, the spines strong, short, curved. Juvenile leaves streaked and dotted with narrow white lines. Epidermis rubbery with a subepidermal layer of longitudinal cells containing a bright-yellow, very bitter latex which is drained, evaporated and utilized in the drug trade as a cathartic called "bitter aloes." The mucilaginous, semi-transparent parenchyma, or "pulp," is slightly or distinctly bitter according to seasonal conditions. The erect, unbranched flower stalk arises in late winter, becoming 3-4 feet tall, with a 12-18 inch raceme of pendent, tubular, yellow, inch-long flowers, much visited by hummingbirds. Numerous offshoots, or suckers, develop around the base of a mature plant and, if not transplanted, form compact clumps several feet in extent.

in cold water, mixed with a little burnt alum, wrapped in muslin and administered to heal "country sore-eyes." The pulp is valued as a cooling application on inflamed joints (20).

In Java the macerated leaves of *A. barbadensis* are used on burns to prevent blistering; the diced pulp, mixed with sirup of rose water and taken internally, is believed to cure early stages of tu-

berculosis and gonorrhea. The mucilaginous juice with sugar is said to relieve asthma and various bronchial complaints (32).

In Stuart's *Chinese Materia Medica* there is no mention of the use of the fresh pulp (65), but M. T. Tchou of Chunking recalls its use on the hair as well as its healing a burn in his boyhood when reporting its successful application to a radium ulceration on his hand in Cleveland in 1939 (68). Cole and Chen cite Liu Yu-hsi's reference to the healing of dermatitis with the fresh aloe leaf in the 8th or 9th Century A. D. (15).

Malayans and Jamaicans bind a slab of the pulp to the forehead to relieve headache and use it as a poultice on burns (3, 11) as do the Mexicans, who also apply it to erysipelas and tumors (42). In the Philippines the leaves of *A. barbadensis* are employed to poultice edema of beriberi suffers. The mucilaginous juice is taken with milk for dysentery and kidney pains (52). In Jamaica it is beaten with egg and given as a purge (3). There and in Cuba aloe is a popular remedy for colds, taken either as a decoction of the unpeeled leaf or as an infusion of the pulp in proof rum. A cough sirup is made by cubing and washing the pulp, pressing it in a cloth to squeeze out all bitter juice, then boiling it in water for an hour, straining and boiling again with two parts of sugar. This sirup may be taken alone or added as a sweetener to tisanes or other beverages (55).

In Central America and northern South America the pulp is valued as a mild laxative (2, 62), and in these areas, as in Africa, because of its bitterness it is rubbed on mothers' breasts to wean infants (63, 72). In Colombia children's feet and legs are coated with the juice to protect them from insects; and an entire plant is often suspended from the ceiling of native shops to repel flies (2).

Africans employ a cold infusion of the leaves of *A. saponaria* to raise the hair on hides prior to tanning. An infusion is also given to poultry for enteritis and indigestion and to calves for "blood scours." *A. arborescens* Mill. is utilized in much the same way. The juice of *A. ferox* is used to treat scab on sheep (72). In the West Indies and south Florida aloe leaves are cut up and added to the drinking water of poultry during moulting and to cure pip (55).

Filipinos blend aloe pulp with wine and apply the mixture to the head to preserve the hair. For the same purpose and as a treatment for baldness the pulp is mixed with a saponiferous infusion of the macerated seed or bark of *Entada phaseoloides* Merr. The latter is irritating to the eyes but is, nevertheless, a common ingredient in Philippine hair tonics (52). In Java and Malaya the liquified pulp alone is massaged into the scalp and hair to improve its condition and to stimulate growth (32).

Grisebach states that *A. barbadensis* was introduced into the West Indies either from the Canary Islands or Bermuda (30). As early as 1596 specimens were carried back to England (17). Masters in *The Treasury of Botany* says that sailors brought home aloe plants with tarred cloths tied about the cut stem and that Dr. Pareira had one hung from his ceiling for two years "still alive and growing" (37). In the French West Indies the plant is generally known as "sempervive" (9, 21), less commonly as "laloi" (5). Where Spanish is spoken, it is called "sábila" or "zábila" (2, 5, 36, 42, 55). Governor Lefroy recorded the colloquial name of "bamboo" in Bermuda (7), and it may be assumed that the plant was carried from there to Florida (probably via the Bahamas). It was not, as is often supposed, introduced by Perrine. J. K. Small relates that "its abundance on one of the Florida Keys has led to the naming of the island Bamboo Key" (61).

Cultivation on the mainland, other than as a dooryard ornamental and household

Fig. 2. At Palm Lodge Tropical Grove, Homestead, Florida, *Aloe barbadensis* is interplanted with avocado and mango trees on oolithic limestone. Without partial shade, the aloe plants would suffer both sunburn and cold damage in the dry winter season.

remedy, began when six plants were given to the late Col. H. W. Johnston, a Kentuckian who started a collection of tropical fruit, spice, medicinal and other economic species near Homestead in 1912, naming his estate Palm Lodge Tropical Grove. He developed an aloe field (Fig. 2) and by 1920 was regularly harvesting the large leaves, drying them in his attic and shipping them to pharmaceutical concerns presumably for the extraction of aloin. His enthusiasm for the fresh pulp was aroused when a man named Allen burned his hand severely with hot tar. Slabs of pulp were kept in contact with the injury, and healing was so rapid and complete that Col. Johnson launched into the selling of the fresh leaves through local markets and shipping them to individuals all over the country. His customers employed the pulp on skin afflictions or as a massage for arthritic joints or took an infusion internally as a mild laxative or for stomach ulcers. For the latter pur-

poses the pulp is generally diced into a jar, covered with water and kept in a refrigerator. A small dose of the resulting slimy liquid is taken once or twice daily. Because of its consistency it is difficult to pour out the desired amount, and I have found that a more manageable product results from liquifying the pulp of one leaf with a halfcup of water in an electric blendor.

For some years prior to Johnston's death in 1947 and to the present time, his son-in-law and daughter, Mr. and Mrs. Albert Caves, have kept aloe in cultivation and remained the principal suppliers of the fresh leaves. In the early 1930's Dr. Creston Collins obtained fresh aloe leaves from Johnston and with his father, C. E. Collins, for many years Health Officer of Crisfield, Maryland, began incorporating the pulp into an ointment or salve. The two men were deeply convinced of the efficacy of fresh aloe in cases of burns and other skin damage and in 1935 reported jointly on its use in an instance of x-ray dermatitis in the *American Journal of Roentgenology* (16). This aroused interest on the part of others in the medical profession, and similar reports of the apparently successful use of aloe pulp, rind or ointment in the treatment of radiation and other burns appeared during the next six years (18, 24, 38, 41, 53, 76). Rowe, Lovell and Parks expressed the belief that "the healing agent is concentrated in the rind" (59). Lushbaugh and Hale, reporting the treatment of radiation burns on rabbits with "fresh whole leaf" and also leaf ointment, concluded that these materials must contain growth-stimulating substances which hastened both the degenerative and reparative phases of the lesions (39).

Many investigators have endeavored to establish the active principles of the fresh aloe leaf. Roboz and Haagen-Smit reported extracting from the parenchyma and "assimilatory tissue" a mucilage in the form of a white powder containing glucose, mannose and a little uronic acid (54). Filatov and Biber announced the finding of biogenic stimulators in aloe leaf extracts (23). Benigni noted antibiotic compounds in aloe (6), though tests by Fly and Kiem in 1951-52 with the clear pulp, the green vascular portion and the whole leaf showed no antibiotic effect against *Micrococcus aureus* and *Escherichia coli* (26). Wasicky and Hoehne found 2.91% saponin in *Aloe barbadensis* leaves (70). Freytag (27) and Sysoev (67) attributed wound-healing hormone activity to aloe leaf tissue.

The pioneer work of Creston Collins in preparing and marketing an ointment from aloe pulp has been continued in a limited way by his widow with some improvement in keeping quality and increase of aloe content from 40% to 70%. In the past ten years other experiments have produced not only competitive creams but also cosmetic and suntan lotions, shampoos, hair conditioners, baby powders, tonics and mixtures for stomach ulcers. Some of the products contain lanolin or Allantoin (a skin softener), Bithional (an antiseptic), colloidal sulphur, or benzoic acid (a preservative). In 1958 two Russians patened an emulsion with a 78% aloe juice content for preventing and treating skin diseases (56).

A current "boom" in this small industry in Florida is spurring expansion of plantings, and aloe culture and processing are being initiated in the Rio Grande Valley of Texas (1, 69). A few efforts in Florida to extend cultivation north of Miami have met with little success because of poor location or lack of understanding of the plant's requirements. Aloe can be cultivated successfully only in the warmest areas and preferably in partial shade. Acceptably fleshy leaves are obtained only by daily irrigation in dry seasons and heavy fertilizing. No systematic research has been undertaken to determine seasonal variations in composi-

tion, the ideal stage at which the leaves should be harvested, or any other factors which would aid in establishing uniform quality.

Processors, usually inadequately financed but heavily armed with Biblical references (which are entirely inapplicable to the fresh leaf) and portfolios of testimonials from laymen, laboratories, doctors, hospitals, and administrative personnel of the government seek official recognition of the virtues of their respective products. Much of the documentary evidence is impressive, but the exploitation of aloe preparations has been accompanied too often by misinformation and exaggerated claims in advertising literature and commercially-inspired articles in the press and popular periodicals. In a persistent myth the use of aloe leaf pulp in surgery and otherwise is traced to the Florida Seminoles. This is not borne out by the ethnobotanical studies of Dr. William Sturtevant of the Smithsonian Institution (66), and it is flatly denied by the tribal medicine men interrogated by Mr. Albert DeVane of Lake Placid at the request of the writer (19). Such tales only add to the "patent medicine racket" aura and repel many whom the exploiters desire to impress.

On October 13, 1959, Lt. Col. Hamitt, Surgical Research Branch, U. S. Army Medical Research and Development Command, wrote Delta Pharmaceuticals in Hialeah: ". . . during the past several years the Department of the Army and other governmental agencies have been presented with numerous preparations containing *Aloe vera*. These preparations have been claimed by their producers to be beneficial in the treatment of thermal and radiation burns and possibly for other purposes. So far no conclusive proof has been presented that any of these substances are of any therapeutic value in the treatment of either thermal or radiation burns. On the contrary, there is considerable evidence that these substances are of no value and may actually be deleterious when used for this purpose."

However, regarding the fresh leaf, Dr. E. P. Pendergrass, Professor, Department of Radiology, Hospital of the University of Pennsylvania, wrote the Elberton Laboratory, Elberton, New Hampshire, on November 6, 1959: "We have used the juice from the *Aloe vera* leaf in the treatment of radiation reactions with excellent results. Indeed, it is our feeling that the *Aloe vera* leaf is probably more effective than any of the other preparations now available for the purpose. We have had enough clinical experience to satisfy us as to its value.

In the writer's own experience with aloe leaf pulp since 1945, healing has been observed, notably in the case of a cyst on an eyelid and also in cases of badly chapped hands and gastric distress. It is possible that the seeming efficacy of aloe pulp may be attributable not to any "miracle ingredient" but merely to the fact that it is 96% water (22) and provides a means of making water available to injured animal tissue without sealing it off from the air. This thought is supported by recent indications that cold water may be the best emergency treatment for burns. (Cfr. Shulman, *Jour. Amer. Med. Assn.* 173: 1916-1919).

The fresh aloe leaf, cut from the plant close to the stem, is soon sealed at the base by exuding latex and, if undamaged, remains in good condition for two or three weeks without refrigeration (Fig. 3). Nonetheless, extensive employment of the bulky unprocessed leaf would be obviously impractical. A convenient and possibly superior form may be the powered product. "Epithal," evolved by Dr. Alexander Farkas of North Miami Beach. He states it to be a gucosidal compound derived from the chlorenchymal layer of the parenchyma (1 ton of leaves yielding from 4 to 6 ounces) in a saccharose carrier prepared from the clear central pulp. Dissolved in water (7.5 grams in a half-

Fig. 3. The fleshy, rubbery-skinned, white-based leaves of *Aloe barbadensis* are severed from the plant close to the stem. A little of the yellow latex seeps from the narrow slit at the base and, on drying, seals it effectively. The latex soon turns reddish and makes an indelible maroon stain, as seen on the waxed-paper under the improperly cut leaf at the left. The sharp thorns are a hazard to aloe leaf harvesters.

pint), it becomes mucilaginous and may be taken internally or sprayed or otherwise applied to burns or other injuries. Drying in a few minutes, it serves as a dressing and thus lends itself to the current practice of exposure treatment (22).

Neither the powder nor the solution can be held for long at room temperature but under refrigeration will apparently keep indefinitely without deterioration. This or any similar concentrate of undiluted aloe pulp, equally hygroscopic, makes possible much wider utilization of the water-holding virtue of aloe and should facilitate controlled experimentation to determine whether or not it truly possesses other significant healing attributes as well.

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Notice of New Serial

Volume 1, Number 1, of Radiation Botany appeared September, 1961. It is an international journal devoted to plant radiobiology and closely related topics. Dr. A. H. Sparrow, Brookhaven National Laboratory, is Editor-in-Chief, and the journal is published by Pergamon Press, New York. Annual subscription rates are $20.00 for libraries and $10.00 for individual subscribers. It is expected that about 400 pages will appear yearly in four issues.

Although all aspects of radiobiology of plants (including fungi) will be considered, the journal will be primarily concerned with the effects of ionizing radiation on plants or plant structures. Technical aspects of apparatus and techniques will also be included. Original contributions in English, French or German are accepted, and brief reports, letters to the Editor, book reviews and invited review articles will be published.

The physical appearance of the first issue is satisfactory with a double column format, adequate sub-headings and excellent reproduction of figures and plates. The board of editors is distinguished and international.

Sufficient research on the radiobiology of plants, if broadly interpreted, is currently being conducted to warrant the publication of this new journal.

RICHARD M. KLEIN
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Corn's Evolution and its Significance for Breeding[1]

WALTON C. GALINAT[2]

In the future, corn. (*Zea Mays* L.) breeding may be based upon more than a knowledge of genetics. Its methods may reflect also a greater understanding of the evolution of the corn plant. A knowledge of corn's previous evolution could aid man in adjusting new characteristics or in projecting old characteristics so as to maintain the delicate relationships evolved by nature which adapt form and function to the environment. Also, in modern hybrid corn, the breeder has gathered and recombined some of the qualities of vigor that diffused from ancient hybrids between corn and its relatives, teosinte and *Tripsacum*, even though he may not know the exact origin, quantity or quality of these factors. Therefore, an understanding of the previous evolution, structure and function of the corn plant, as well as the past and potential contributions of germplasm derived directly from corn's relatives, should lead to a more intelligent and efficient approach to breeding.

Already, the advantages in applying nature's solution to certain breeding problems are coming to light. The rapidly evolved, long-eared selections made by the corn breeder, for example, do not always fulfill their potential in yield because of reduced set of grain at the base of the ear; as a result, such selections may be less productive than those which develop two or more shorter ears on each plant. Yet the long-eared, open pollinated varieties, such as 'Longfellow Flint' from the United States, 'Jala Dent' from Mexico and 'Huesillo' from Costa Rica, have evolved an ability to produce full sets of grain. Therefore, a study of the patterns involved in the evolution of longer ears should reveal what the corn breeder must do to extend evolution for longer ears with full sets of grain.

In the perfect-flowered relatives of corn, such as *Manisuris* of the SORGHUM tribe, a small size for the sexual parts (styles, anthers and pollen grains) was adequate for pollination because of the close proximity of the sexes in the same flower. But when, during the emergence of the corn tribe, the sexes became separated both on the plant and in time of flowering, certain adjustments, both in size of sexual parts and in type of protective device for the grain, diverged along two parallel lines. In one line, that of the genus *Tripsacum*, the grain became well protected by the "cupulate fruit case," a device formed by a depressed rachis segment and an outer glume of the enclosed spikelet. As a result, the female region became fixed in the lower half of the same spike as that of the male. But in the corn line, protection for the grain became dependent upon an inefficient system of subtending husk-leaves, the nature of which leads to a pattern of dynamic changes.

Our knowledge of the many changes involved during the evolution of the modern corn ear and its protective husks starts with archaeological material over 5000 years old from Bat Cave in New Mexico (Mangelsdorf, 1958a). The tiny Bat Cave ears had a lower grain-bearing region which was only two centimeters long. Although the floral bracts on these

[1] Adapted from a paper presented at the Second Annual Meeting of The Society for Economic Botany, Cambridge, Mass. May 13, 1961.

[2] Bussey Institution of Harvard University, Jamaica Plain, Mass.

tiny ears almost covered the grain, protection against bird feeding by this means must have been incomplete. As a result, the Bat Cave ears had evolved supplemental protection from three or four husk-leaves borne below on the shank. Then for the next few thousands of years starting when the husk system became the sole means to protect the grain, the evolution and survival of corn has been largely in the hands of man.

But the husk coverage for grain borne near the tip of the ear was never quite adequate. Thus, when the problem of dispersing seed from a husk-enclosed ear was overcome by the intervention of man, the selective pressure was for longer and more numerous husks combined with a condensation or fasciation of the ear down into these husks. These conditions were met by a retraction of the female region as a lateral inflorescence while the terminal inflorescence or tassel became exclusively male and specialized for pollen dispersal.

The evolution of a more adequate husk system to protect the ear has been coincident with the evolution of a larger ear. Several of the changes involved are illustrated by the sequence of ear-types which occur along the stalk of a certain primitive race, Argentine popcorn (Fig. 1), as first published by Mangelsdorf, 1958a. The tiny ear borne immediately below the tassel is similar to the tiny Bat Cave ear in size and in lack of good husk protection. Proceeding down the stalk, the ears become larger and the "shanks" which the ears terminate become longer. The longer the shank, the greater the

Fig. 1. Diagrammatic longitudinal section of a many-eared stalk of Argentine popcorn which illustrates several of the changes involved in the evolution of the modern ear. Proceeding down the stalk, the ears become larger and the "shanks" which the ears terminate become longer. The longer the shank, the greater the number of nodes from which the husks arise and the longer and more numerous the husks, the more complete the enclosure of the ear.

TABLE I
THE ASSOCIATION OF POLLEN GRAIN SIZE WITH EAR LENGTH IN CORN

Race and stock	*Ear length (cm)*[1]	*Pollen size (μ)*[2]
Nal Tel, Mex. 1749	7.9	81.2
Polomero Toluqueño, Mex. 1757	10.2	77.4
Tepecintle, Mex. 1718	10.4	79.1
Conico, Mex. 1751	13.6	89.5
Cacahuacintle, Mex. 1758	14.5	82.9
Tabloncillo, Mex. 1779	16.4	101.4
Vandeño, Mex. 1719	17.2	83.9
Tuxpeño, Mex. 1750	19.7	95.0
Jala, Mex. 1787	30.5	101.4
Huesillo, Costa Rica 1045[3]	33.0	106.2

[1]from Wellhausen *et al* (1952)
[2]from Mangelsdorf, P. C. (unpub.)
[3]Ear length from same specimen as pollen sample.
r = 0. 881* (coefficient of simple linear correlation) with 9 degrees of freedom at 1% level, significance = 0.735* (Tables of Snedecor, G. W., 1955)
*Highly significant since r is greater on the 1% level.

number of nodes from which the husks arise and the longer and more numerous the husks, the more complete the enclosure of the ear. In the large modern ear, all of the energy has become concentrated into a single large ear located at the most favorable position for the high yield which, in the case of the Argentine popcorn shown in the diagram (Fig. 1), would be the second ear up.

The increase in length and number of husks during evolution of the modern ear forced adjustments in other characteristics. When the ear became laterally enclosed by these husks, the styles had to acquire an ability to elongate up beyond the tips of the husks in order to become exposed for pollination. This elongation had to be extreme for styles originating on the lower part of the ear. But, as these styles became longer, the pollen had to acquire an ability to send its tubes down increasingly greater distances. Thus, there are several dependent factors involving the husk, the style or the pollen anyone of which could become limiting to an extension of evolution for increased ear length.

The failure of seed to develop at the base of extremely long ears, such as those selected by the corn breeder, might result from an inability of the pollen available to send its tubes all of the way down the extra long styles from this region. The fact that pollen from corn's relative, *Tripsacum*, is both small, having only about one-half the diameter or one-eighth the volume of food reserves and cytoplasm as that of modern corn pollen and its tubes have only short penetration ability in the long styles of corn, provided an important clue:—that of pollen grain size in relation to the ability for prolonged pollen tube growth. Since the styles of *Tripsacum* are short, there was no selective pressure for pollen capable of prolonged tube growth. Likewise, the tiny ears of primitive archaeological corn must have had rather short styles and also have lacked pollen capable of prolonged tube growth.

With this in view, I decided to plot out pollen grain size and ear length data already available on the Mexican races of corn. Although the sample size of 25 pollen grain measurements for each race was too small to illustrate the total variation (by standard deviation), the results for the sample measured, as shown in Table I, are an almost perfect correlation between pollen grain size and ear length. As might be expected from the discussion, the most primitive races had the shortest ears and smallest pollen, while

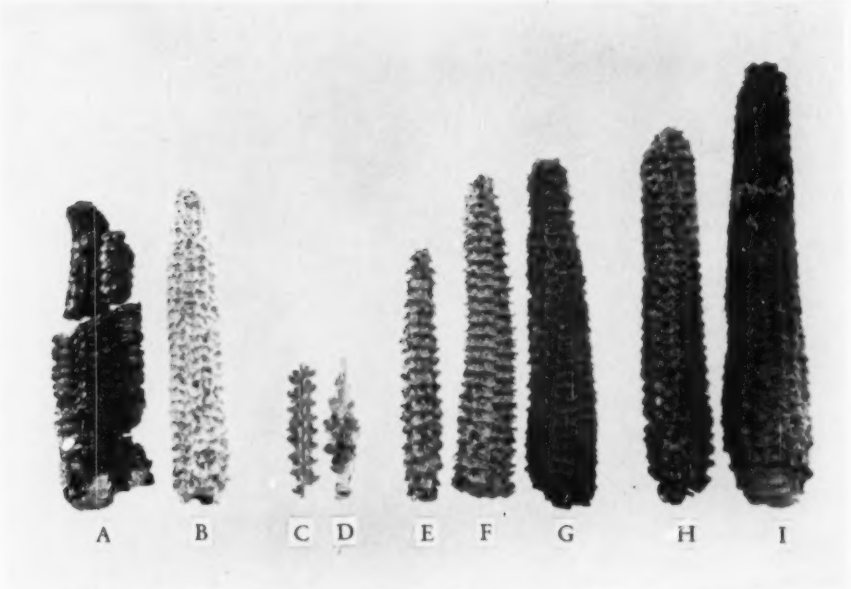

Fig. 2. A series of cobs from the various levels in Cebollita Cave. The original 'Chapalote' corn (cob A) of Level 5 has some non-carbonized counterparts (cob B) in Level 4. Note the soft glumes of cob B. Level 4 also contains many small highly tripsacoid cobs (C, D) similar to segregates of experimental hybrids between corn and teosinte. Although Level 3 (cobs E, F, G) marks the beginning of a progressive decrease in the indurative effects of the teosinte introgression, the variability which it had introduced continues to increase. Finally in Levels 2 and 1, there is almost complete recovery from the detrimental effects of introgression and many of the cobs (H, I) are larger and probably more productive than the original 'Chapalote' corn. Slightly less than one half natural size.[1]

[1] from Galinat and Ruppé, 1961.

the most evolved races had the longest ears and the longest pollen. Thus, it seems that as the short-eared primitive corns evolved into long-eared corns, they also necessarily evolved larger pollen.

If the lack of the basal grain set does prove to be just a matter of too small pollen, as the preliminary data suggest, then the corn breeder might overcome his difficulty in selecting long ears with full seed-set by increasing pollen grain size as well as ear length. By just planting the kernels from the base of long ears, he may automatically select for larger pollen with an ability to send its tubes down longer styles. Ordinarily the so-called "large rounds" which screen out from this region are not planted because they do not drop properly in mechanical corn planters. In addition, the common practice of corn breeders to cut the husks and styles back to the tip of the ear before making hand-controlled pollinations tends to eliminate selective pressure for pollen able to grow down long styles. In more primitive forms of agriculture before the rapid inbreeding involved in hybrid corn production, before the mechanical corn planter and before the use of insecticides and the development of better husk protection against birds, the large rounds actually

had a selective advantage in that much of the grain from the tip of the ear was lost. With these considerations in view, experiments are now in progress to confirm the significance of pollen grain size to basal seed set in corn.

Other problems in corn breeding arise from a reduction in the gene pool after the spread of hybrid corn and from the nature of combining ability which must be bred into the parents of hybrid corn. Studies of archaeological corn suggest that controlled introgression from teosinte and *Tripsacum* may provide a solution to these problems.

In the Cebollita Cave corn from New Mexico, shown in Fig. 2, teosinte introgression seems to have played an important role in both evolution and heterosis (Galinat and Ruppé, 1961). The original corn from this cave (level 5) was perfectly preserved by carbonization and so we could identify it as 'Chapalote,' an ancient indigenous race from the Southwest. The next level up (level 4) marks the start of teosinte introgression, as indicated by the presence of many small highly tripsacoid cobs that are similar to segregates from experimental hybrids between corn and teosinte in having a great increase in the induration of cobs which is correlated to a reduction in cob size. At level 3, the deterimental effects of teosinte introgression on cob size declined, but the variation which was introduced by this introgression continued to increase in higher levels. Finally, in levels 2 and 1, not only is there virtually complete recovery from the detrimental effects of the introgression, but many of the cobs are larger and probably more productive than the original 'Chapalote' corn.

But the indurative effects of the introgression were not always associated with detrimental effects because the longest as well as the shortest cobs were the most indurated or tripsacoid. This parabolic type of relationship is interpreted to be a result of hybrid vigor from heterozygous teosinte germplasm in the long cobs and a reduction or deterimental effect from homozygous teosinte germplasm in the short cobs. This so-called "corn-teosinte" heterosis in this and other archaeological corn (Galinat, et al, 1956) is an apparent progenitor of heterosis in modern hybrid corn.

Heterosis from teosinte germplasm must have had a selective advantage with the result that teosinte introgression fanned out through many generations and hundreds of miles away from teosinte itself. Even now our corn breeders attempt to recapture what is probably a mere portion of the original vigor by recombining its diluted and widespread derivatives. Yet the original sources, teosinte and *Tripsacum*, are available and waiting for the corn breeder to use them.

There is some experimental evidence that teosinte introgression also has a mutagenic action upon corn (Mangelsdorf, 1958b). Consequently, there is a possibility that this effect of teosinte germplasm is responsible for at least part of the great diversity in modern corn. The preservation and adaptation of this diversity was contributed to by the hundreds of Indian communities each of which evolved its own race of corn to fit the local environmental conditions and to facilitate use of the corn plant according to local customs. The occasional exchange and hybridization of corn races as a result of trade or plunder made possible the recombination and selection of new and more productive races. The description and evolution of over 200 of these races from Latin America is already available in a recent series of publications[1] by the National Academy of Science-National Research Council (Pub. Nos. 453, 510, 511, 593, 747 and others yet to allow). The insight gained from

[1]The first of this series which is on the races of maize in Mexico (Wellhausen, *et al*, 1952) is available from The Bussey Institution of Harvard Univ.

such accumulations of knowledge on corn's evolution has deep significance for corn breeding. An understanding of the evolutionary patterns in which the other cultivated plants have evolved should also lead to the development of more efficient methods for their improvement.

Summary

Examples of two ways in which studies of corn's evolution may contribute to its breeding are given. First, the association of increased pollen grain size with increased ear length in nature indicates the necessity of maintaining this association during artificial selection for increased ear length. Second, by understanding the role of introgression (or flow of germplasm from corn's wild relatives, teosinte and *Tripsacum*), we might be able to increase our pool of germplasm and be able to control combining ability, as used in hybrid corn breeding. The use of experimentally controlled introgression obtained directly from teosinte and *Tripsacum* to further improve corn should make it possible to increase the yield and utility of this basic food plant to higher levels than ever would have been attained otherwise.

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Buchu, A New Cultivated Crop in South Africa[1]

The farmers of South Africa have provided the first steps in the domestication of a medicinal herb endemic to the Cape Province.

HOWARD SCOTT GENTRY[2]

Introduction

Good Buchu is *Barosma betulina* (Berg.) Bartl. & Wendl. of the Rue family, *Rutaceae*. The common name is of Hottentot origin with Boer spelling and pronounced as boochoo with the hard Dutch-asperated "ch." The botanical name is more apt; *Barosma* from Greek meaning a heavy smell, and *betulina* from Latin meaning birch-like in reference to the serrate birch-like-leaves. Buchu forms a small, shiny-leaved bush 7 to 9 dm tall with white to pink flowers (Fig. 1). The small ovate or obovate, serrulate leaves are strongly aromatic and pellucid-dotted below with oil glands. With its drought-resistant ability to maintain a bright green color through the dry summer, a prolonged flowering period, and an aromatic nature it has potential as an ornamental. However, its present use is medicinal, since the leaves form the Buchu drug of commerce. In the southwestern Cape Province of South Africa the plant has recently been put into cultivation and the writer was able to take notes on the early cultural stages of its domestication.

Two other species of this genus, *Barosma crenulata* (L.) Hook. and *B. serratifolia* (Curt.) Willd., also enter the drug trade as Buchu, but according to the Afrikaners they are inferior to *B. betulina* and only the last is regarded as official. Youngken (8) designates *B. crenulata* as Ovate Buchu, *B. serratifolia* as Long Buchu and *B. betulina* as Short Buchu, in reference to the ovate leaves, long leaves, and short broad leaves respectively (Fig. 2).

Other aromatic species of *Barosma* and of the closely related genus *Agathosma* are employed locally in folk medicine. The leaves of *B. pulchella* (L.) Bartl. and Wendl. yield ca. 3% of a golden yellow citronella-like oil. The leaves of *Agathosma microphylla* Mey. yield 2-5% of a yellow volatile oil with an aniseed-like odor (7). Harvey and Sonder (3) record more than 100 species in these two genera. Few of them have been investigated for their constituents. In view of the modern intense chemico-medical interest in plant compounds, this volatile group needs more attention from botanists and chemists.

Watt and Breyer-Bradwijk (7) state that as a household remedy the leaves of Buchu have been employed for almost every disease that afflicts mankind. According to Pappe (6) the leaves were formerly used as an infusion to stimulate perspiration in rheumatism and gout, cholera, urinary diseases and dropsy, etc. Its most common local use at present appears to be as a stomachic tonic and as a tincture in brandy. Buchu brandy was observed everywhere through South Africa as a regular stock item upon the hotel bar shelves. Doctors still prescribe it as a diurectic and for various afflictions of the urinary tract in South Africa and it is so employed in other parts of the world as well. The leaves yield 1.5 to 2.5% volatile oil, consisting mainly of

[1] Received for publication 3 Aug. 1961.

[2] Crops Research Division, Agricultural Research Service, United States Department of Agriculture, Beltsville, Maryland.

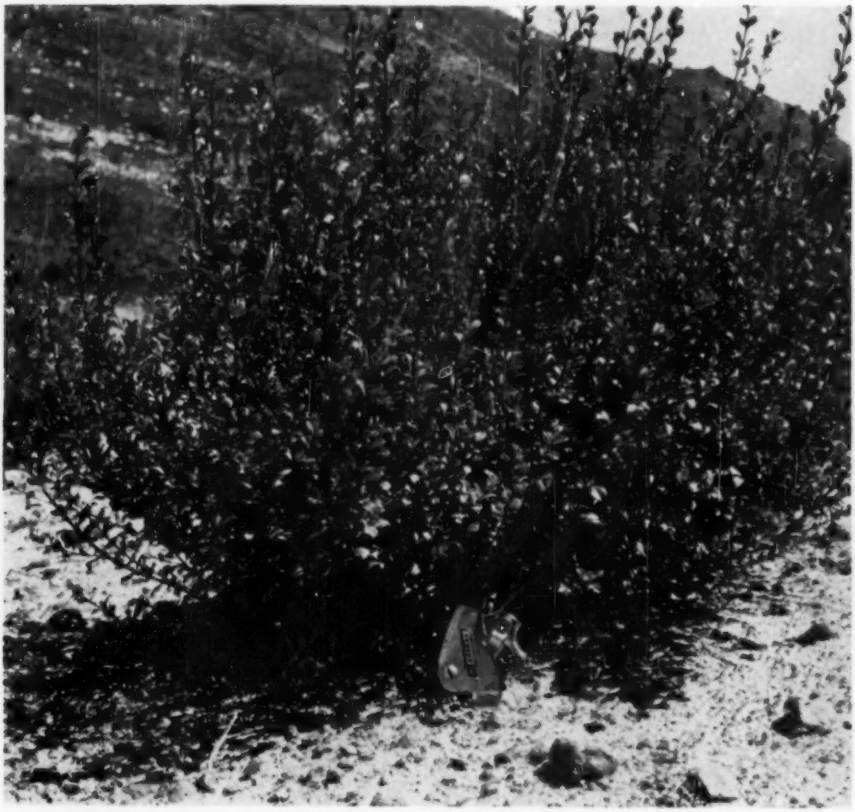

Fig. 1. Cultivated *Barosma betulina* in the Clanwilliam District. The top growth is about 1 year old from an old root crown.

laevogyrate methone (ca. 50%) and diosphenol or Barosma camphor (17-30%). The diuretic action of this drug is ascribed to diosphenol. However, the U. S. Dispensatory in 1955 (5) indicates that although the volatile oil is doubtless antiseptic, the preparations are too dilute to exert much antibacterial action. Perhaps its greatest medicinal virtue is the psycho-therapeutic effect provided by its penetrating, twangy and astringent aroma. It is abhorrant to some people, exciting to others. Irrespective of real or fancied value, it continues in the trade and current spring quotations list it at 50-75¢ per lb. wholesale in barrels at New York dock side (4).

Buchu of South Africa should not be confused with "Indian Buchu" from India obtained from cultivated plants of *Myrtus communis* L. of the family Myrtaceae. The leaves are employed for cerebral affections and diseases of the stomach and liver. An essential oil fraction, Myrtol, is derived from the leaves and is reported as an antiseptic and powerful stimulant to the pulmonary and genito-urinary mucous membranes (2). *Myrtus communis* is native to the Mediterranean Region.

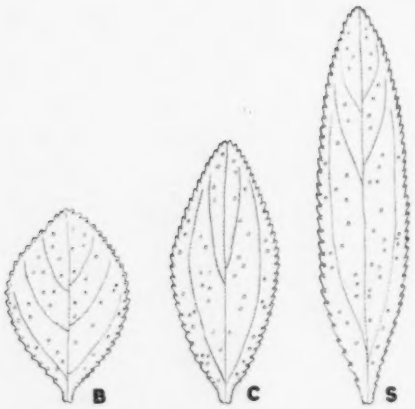

Fig. 2. Drawn from Youngken (8). Leaves of Buchus: B *Barosma betulina* or "Short Buchu," C *B. crenulata or* "Ovate Buchu," S *B. serratifolia* or "Long Buchu."

Natural Habitat

Barosma betulina is native to that small region of extreme southwest Africa having a Mediterranean type of climate, where summers are dry and precipitation is limited to winter. It is common, if not limited to, the rocky mountainous slopes of the western Cape Province between 1500 and 4000 feet elevations. Annual rainfall averages range between 20 and 25 inches in Clanwilliam District, where the plant is common. Rain is said to fall through April to July inclusive, these being comparable to our northern hemisphere months of October to January. During the eight remaining months there is little effective rain and soil-moisture deficiency is severe during the summer and early fall. This climate is homologous to that of southern California. *B. betulina* was observed only on soils derived from less alkaline sandstone and igneous rocks. The plant appears to require coarse soils in well-drained sites and was lacking on the deeper more mature soils of bottomlands, in acidic peaty heath soils, and in grassland. The predominant vegetation with which it is associated is the more open shrub communities of the Fybos, as defined by Acocks (1), comparable to the Mediterranean Macchia and the Californian Chaparral vegetations. These are all fire subclimaxes and as with many members of such plant communities, Buchu is capable of resprouting after fire.

Cultivation

At present Buchu is cultivated only in the Clanwilliam District. The following notes were made during two visits to Kleinfontein, the farm of J. H. Smit, southeast of Citrusdal in the Cedarbergen. The Buchu bush grows wild about the mountains surrounding his farm and has long been cut for market. Smit began cultivating the plant in 1927, about the same time as several other farmers of the district. His methods so far constitute a kind of encouragement to cultural establishment on private land, rather than intensive cropping directed at high production. He simply provided space by clearing off the native Protea-Erica-Legume-Restio shrub, broadcast the wild seed, harrowed it in and provided the light weedings necessary.

The resultant stands (Figs. 3 and 4), are widely spaced and entirely rain-fed. Smit has presently about 2 morgens, or 4¼ acres, in cultivation. The plants have responded best on sandy to gravelly soils (derived from sandstone), but failed to establish themselves on heavier soils. Smit has made repeated sowings and finds it best to plant in time for the first winter rains so that seedlings have time to develop adequate roots to carry the plants through the long summer dry period. He reports successful transplant of seedlings by moving them with shovel from one part of the field to another in order to even the stand. Young plants are topped to stimulate stooling.

Harvest

From the time the plants are four or five years old the tops are harvested

Fig. 3. Mature Buchu plants on the Smit farm of Kleinfontein. The tops are nearly two years old and will be cut in another month.

every other year. The stems are cut three to five inches above the root crown when the leaves are mature and begin to show yellow along the lower portion of the stems; in Clanwilliam District this is in mid-December of summer. The older plants were fruiting at this time and bore mature seeds. The cuttings are spread out to dry in the shade. Smit laid his in the loft of a barn. After a few weeks of drying the leaves are shaken off the stems and put through a small cleaning machine to eliminate small pieces of stems and other debris. Drug purity standard requires that Buchu leaves contain no more than 8% of stems nor more than 2% of other foreign matter. The shade-dried, cleaned leaves are then placed in sacks or barrels for shipment.

Native collectors of the wild Buchu use essentially the same procedure. One man can collect about 200 lbs. of leaves, dry weight, per day. They build temporary drying racks in the veld and shade the collected foliage there-on with brush. After drying, the leaves are stripped off

the branches and transported to the farmers for machine cleaning. The wild stands are reported to produce a much larger portion of the product than cultivated plants.

Two local animal pests are present on the Smit farm. One is a worm infecting the roots which in time kills the plant. Sap-sucking beetles cause marked leaf curl and stunting. Some of the wild antelope, like the Rhebock, eat the seedlings and the young shoots of regrowth following brush fires. The oldest plants on the Smit farm are presently over 30 years of age and show no age deterioration.

Future Outlook

Smit reported the uncertain market for Buchu as the main deterrence to the commercial development of Buchu as a crop. Local prices have varied from 15 shillings ($2.10) per lb., during World War II, when it was liberally prescribed by army doctors, to 2 shillings (28¢) per lb. in 1959. He calculated it would be a profitable crop at about 5 shillings (70¢) per lb.

The present stage of Buchu domestication is an example of local initiative in bringing a plant resource under control. In this instance the first step was made

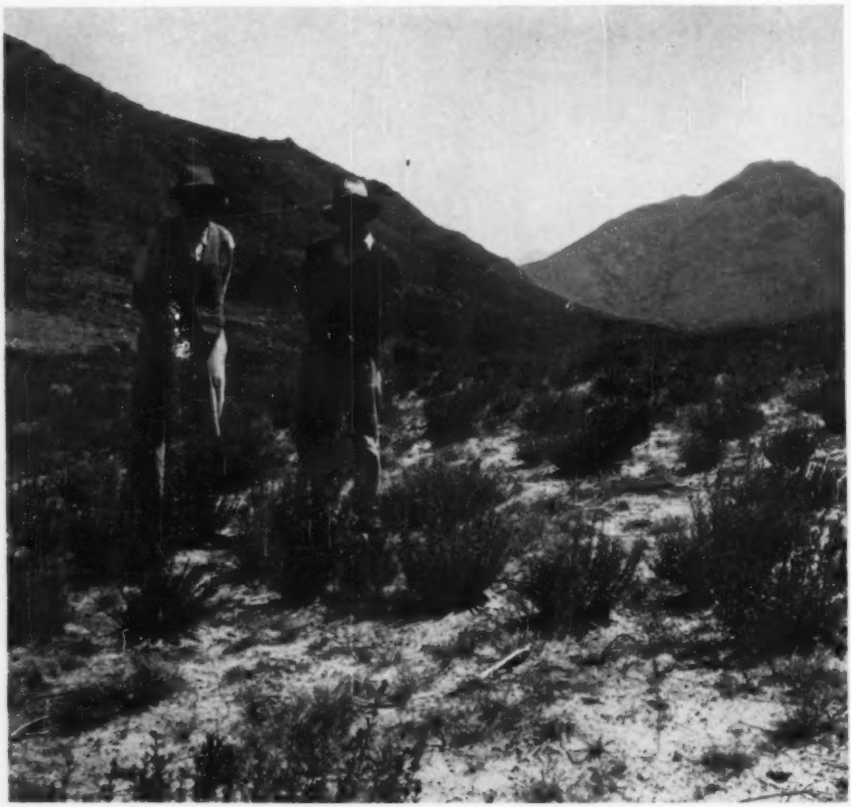

Fig. 4. J. H. Smit and son in a young planting of Buchu on their farm in the Cedarberg.

in the locale of the plant's natural environment, like the North American cranberry, but quite unlike the domestication of the *Hevea* rubber tree, where cultivation was first established on a continent far removed from its origin. The future of Buchu will depend upon its eventual use. Medicinally its prospects appear uncertain, but new uses, perhaps as an ornamental, may carry it far into the future and to remote lands.

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Seed Technology [1]

DUANE ISELY[2]

The term seed technology is employed in several senses. Herein, I am circumscribing it in a restricted connotation, essentially synonymous with seed analysis and concerned with seed quality evaluation.

Seed technology may be regarded as a highly specialized field. Its practitioners form a closely knit group. It possesses its own literature which is perhaps characterized by all too little introgression with related areas of activity. On the other hand, seed technology can be interpreted as a broad phrase of economic botany, involving not only basic and applied plant science, but industrial and legal practices and problems. It is concerned with economics of seed marketing and the purchasing attributes of the seed consumers. It inevitably interrelates with seed production, processing, and quality control.

Analysis Methods

Standardized Testing Procedures. Tests for the purity, germination, and noxious weed seed content of agricultural and vegetable seeds are made in accordance with a prescribed set of procedures: the Rules for Testing Seeds (3). The International Rules for Seed Testing (23) are employed primarily for seed moving in international commerce.

Standarized seed testing procedures are essential. As seed lots move in commercial channels, they are bought and sold on a quality basis. Furthermore, seed laws require that quality be accurately and specifically labeled; state and federal agencies inspect and test seed in connection with the enforcement of such legislation. By the time a typical seed lot has reached the consumer, its quality will have been repeatedly verified. If reproducible test results are to be achieved, codification of methods is necessary.

The Purity Test. The purpose of the purity examination is to determine the composition of a seed lot. The examination is made upon a seed sample (Fig. 1, 2) representative of the lot in question. This analysis sample consists of approximately 3,000-5,000 seeds (minimum sample size as designated in the Rules ranges from ½ gram for seeds the size of bentgrass, *Agrostis* spp., to 500 grams for soybeans, *Glycine max*). Four components are separated: pure seed, other crop seed, weed seed, and inert matter. Precise definitions of each of these components are included in the Rules for Seed Testing (op. cit.). In general, the pure seed is that of the designated kind and fragments larger than one-half the original seed. If the seed lot consists of a mixture of more than two crop species (or in some instances, agricultural varieties which can be distinguished by seed characters), each in excess of 5% of the total, both are considered as segregate components of the pure seed. Other crop seed is as indicated by name: for example, red clover (*Trifolium pratense*) frequently contains some sweet clover (*Melilotus* spp.), or timothy (*Phleum pratense*). Weed seeds vary widely as to species and quantities. They may range from a trace in carefully processed seed to 20 or 30% in rough or farm-run seed. Individual weed seed species are ordinarily identified and the number in the sample recorded. Inert material consists of anything not included in the above categories, broken fragments (½ or less) of crop

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[2] Dept. of Botany and Plant Pathology, Iowa State University, Ames, Iowa.

Fig. 1. Purity room of a seed laboratory. "Work board" separations and weighing of components are in progress. The woman standing, middle rear, is operating an air-blast separator.

seed, dirt, straw, and any other foreign material (Fig. 3).

The constituent particles of the various components are usually separated by hand manipulation and visual observation. Tweezers or similar tools are employed. Mechanical aids facilitate certain operations: e.g., air blast separators to remove inert material (largely empty florets) from the pure seed in chaffy grasses. (Fig. 4).

After separation, the four components are weighed and the percentage of each calculated: e.g. 90.00% pure seed, 5.00% other crop seed, 2.00% weed seed, and 3.00% inert matter.

Considerable technical skill is necessary for conducting purity tests. Many crops and planting mixtures are tested. Different kinds of handling and interpretational problems are encountered with nearly every species.

Purity analysis, likewise, entails a considerable knowledge of seed identification. The seeds of several hundred weed species are frequent components of commercial seed in the United States. Many weed seeds are reasonably simple to determine but some closely related species which possess a differential economic significance present critical problems. For example, quack grass (*Agropyron repens*) is a noxious weed prohibited in many states; its related congener, western wheatgrass (*A. smithii*) is a crop plant possessing "seeds" (mature florets) distinguishable only by minute details (Fig. 5). Distinctions between many crop seeds are similarly of a technical nature. Considerable familiarity is required, for

Fig. 2. Dividing and mixing oat sample prior to analysis.

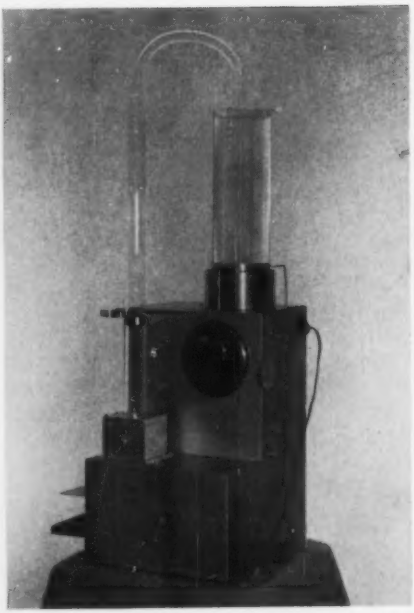

Fig. 4. An air blast separator. A graduated vernier wheel on the right operates a worm gear which controls the air intake gate. Seeds in the blowing tube can then be subjected to uniform and reproducible air pressures.

instance, to separate the seeds of the common agricultural species of *Poa*, of *Agrostis*, or of *Trifolium* which frequently occur in mixtures. Stereoscopic magnification (10 — 30×) is essential to facilitate the analysis and identificaton of small-seeded kinds.

Germination Tests. The germination

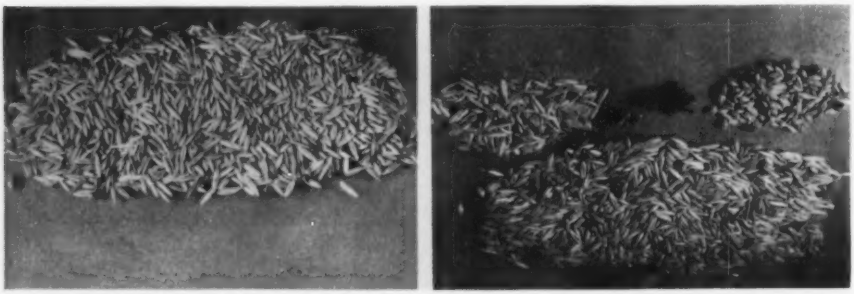

Fig. 3. Left. *An uncleaned oat sample prior to analytical separation.* Right. *After separation: bottom, pure seed; upper left, inert material, mostly empty oat florets; upper middle, weed seeds; upper right, other crop seed, largely barley, wheat and sweet clover. The grass florets slightly to the left of the remainder of the weed seed fraction are those of quackgrass, a noxious weed.*

Fig. 5. Agropyron—*florets (basal portion) of 3 similar species. Left,* Agropyron trachycaulum (*fine pubescence on callus*); *middle,* A. smithii (*transverse furrow above callus*); *right,* A. repens *transverse bulge or ridge above callus.*

test is a measure of the ability of the seeds to produce plants. The seeds are planted (400 seeds in four replicates of one hundred each) under conditions believed to be favorable or optimum for the species involved (Fig. 6). Temperature, humidity, and presence or absence of light are standardized. (Seed technologists have been employing controlled-growth chambers for 60 years.) The substrata and the use of chemical stimulants are specified in the Rules.

Controlled temperatures include both constant and alternating conditions. They range from 10°C. for a cool weather crop like spinach (*Spinacea oleracea*) to an alternating 20-35°C. for warm weather grasses (e.g., Bermuda grass, *Cynodon dactylon*). Special measures are required for breaking the dormancy of delayed-germination species. Pre-chilling, the equivalent of low temperature stratification of horticulturalists, is the most broadly useful procedure. The use of light and the employment of a dilute solution of potassium nitrate as a moistening agent are likewise frequently helpful in "stimulating" the germination of slow-responding seeds.

"Reading" the germinations is not merely a matter of counting the sprouts which have emerged. Seedlings are frequently injured, partially necrotic or physiologically weak (Fig. 7). These conditions may result from seed immaturity, disease, insect attacks, age, or deterioration as a consequence of unfavorable storage conditions. Mechanical in-

jury may ensue as a result of harvesting and processing procedures (Fig. 8). In many instances, germination is initiated but continued growth is not possible. As far as the farmer is concerned, such seeds are equivalent to dead ones; they will never contribute to the field stand. It is, therefore, essential for the analyst to distinguish between so-called normal and abnormal sprouts. Since seed structure and the nature of the usual types of injuries or weaknesses vary from species to species, it has been necessary to prepare precise criteria for such distinctions for each specific crop.

Field emergence is usually lower than laboratory germination. In other words, it cannot be justifiably stated that the germination test will predict field stand. The exigencies of field conditions usually result in the loss of a certain percentage of the live seeds planted. Whether this is a small or large proportion will depend both upon the particular field conditions and the seed kind. On the other hand, the germination test does determine the

Fig. 7. Beans, normal (right) and abnormal sprouts: The epicotyl has failed to develop in the two abnormals. In addition, the one on the left possesses an abortive root.

Fig. 6. Pneumatic counter for planting seeds on an artificial substrate.

Fig. 8. Soybean embryo: mechanical injury as a consequence of harvesting and/or processing procedures. Note lesion in hypocotyl and crack in cotyledon.

maximum potential of a seed lot. If only 50% of the seeds are capable of producing normal sprouts, one can be certain that no more than 50% will grow in the field.

Noxious Weed Seed Examination. The noxious weed test is similar to the purity test, but larger samples of seed are employed. For example, 5 grams of seed are required for a purity test of red clover (*Trifolium pratense*) whereas 50 grams are necessary for the noxious weed seed examination. The larger sample is examined to provide a higher degree of accuracy in the determination of the presence and rate of occurrence of specific "noxious" species. No attempt is made to separate or count other weed seeds.

What are noxious weeds? In general, they represent those species classically considered to be most harmful to agriculture, especially persistent perennial types: e.g., quackgrass (*Agropyron repens*), Johnson grass (*Sorghum halepense*), leafy spurge (*Euphorbia esula*), horsenettle (*Solanum carolinense*), Canadian thistle (*Cirsium arvense*), etc. Legally, noxious weeds are those specifically designated as "noxious" by state and federal laws.

There are approximately 120 noxious weeds listed in the state laws of the United States. Although important weeds differ from region to region, a high proportion of our most significant species are widely distributed. Therefore, the number of noxious weeds designated by the various states seems somewhat excessive. The situation has led to the facetious definition that a noxious weed is one growing close to a legislator.

Because of recent advances in mechani-

cal and herbicidal methods of weed control, the importance of perennial noxious weeds has been somewhat ameliorated. The so-called common weeds in many agricultural areas have assumed a major position in reducing the quantity and quality of crop yields. Perhaps changes in our concepts of "noxious" are in order.

The importance of weed seed examinations is emphasized by the fact that man is and has been the principal effective agency in the dispersal of weeds about the world. Primarily he has distributed them as adulterants in crop seed. For example, giant foxtail (*Setaria faberii*) was rare in the central United States as recently as 15 years ago. But once introduced into seed stocks of legume and grass forages, it has abruptly become one of the most common and pernicious of summer annuals. In Iowa, none of the eight species designated as primary noxious are native to that state. Only one (horsenettle, *Solanum carolinese*) occurred on the North American continent prior to the coming of the white man.

Other Seed Testing Considerations

Seed Identification Literature. Papers treating seed identification and classification number in the hundreds. Unfortunately, many of them have been published as obscure pamphlets or in poorly distributed journals and do not appear to be well known to systematic botanists. The following are examples, a number of which provide reference to further citations: (6, 7, 15, 20, 22, 24, 25, 27, 30, 31, 34, 35, 36, 37, 38, 39, 40, 47, 48, 50).[3]

Determination of Crop Seed Origin (Provenance). Frequently a purity analyst can, by determination of weed seeds present in a seed lot, indicate the production area from which the seed came, or ascertain if it is of mixed origin. A few years ago, adulteration of northern alfalfas with physiologically unsuitable (but cheaper) southern types first came to attention through the presence of seeds of *Polygonum argyrocoleon* which in the United States is essentially limited to southern California and adjacent Arizona. With broad experience, a purity analyst can often determine the approximate origin of crop seed from any area in the world.

Quick Viability Tests. Purity and noxious weed seed examinations can be made within a few hours time. Seven to twenty-eight days are usually necessary for a determination of seed germination. The time required must be considerably extended if the seeds possess a deep-seated dormancy which must be broken prior to emergence. Therefore, for many years, there has been a need for practical and reasonably accurate methods of quickly assessing seed viability. This requirement has been especially felt by seedsmen who must frequently buy seed lots with no information as to their viability but must sell the processed commodity on the basis of germination quality.

Numerous techniques are capable of providing estimates of seed viability: e.g., electrical conductivity, vital stains, and the chemical characteristics of leachates. In general, these procedures are not capable of yielding sufficiently accurate results for practical utilization. In large part, the tests must be performed upon a mass of seeds. If refined to an individual seed basis, the tests, nevertheless, assay the physical or chemical characters of a seed as a whole. However, seedling weaknesses (or complete failure of emergence) are frequently an attribute of specific parts of the seed or organs of the seedling. Not until Lakon (32, 33) proposed the "topographical method" in which differential staining reactions of the various parts of the embryo were scrutinized, was it possible to obtain predictions of viability approximating actual germination results.

The chemical 2,3,5-triphenyl tetrazoli-

[3] As this article is submitted, a forthcoming "Seed identification manual" by Martin and Barkley has been announced by the University of California Press.

um chloride, taken up by Lakon (33) after first experimenting with selenium compounds, has continued to prove the most useful for estimating seed viability. The test is based upon the *in situ* reduction in living tissues of the colorless tetrazolium to an insoluble, colored formazan. The dehydrogenase enzymes constitute the specific metabolic mechanism which is involved in the reaction (43). Further studies of the applicability of the procedure include: (5, 18, 19, 26).

Another type of a quick test is the embryo excision procedure. It has been advocated by Flemion (12, 13) for seeds of woody, horticultural plants whose deep-seated dormancy may take months to break. This test is conducted by removing embryos from the seeds and placing them upon a moist substrate. Although dormant, the live embryos show evidence of ability to grow while the dead or weak ones do not. On the basis of comparative tests, Flemion and Poole (14) believed the tetrazolium test to be inferior to the embryo excision method for a number of kinds of seeds of woody plants.

Moisture Content. Determination of seed moisture relates to the prediction of the future of a seed lot in storage rather than to its current performance. Unfavorable moisture levels may ensue as a consequence either of initial incomplete drying, or from secondary water vapor pick-up in high humidity storage. Although high moisture levels result in seed deterioration, the tolerances of seed kinds vary, and are secondarily affected by other factors. In general, most seed can be carried over a single season's storage at levels in the neighborhood of 10-12%. Methods of moisture determination are summarized in the U. S. Department of Agriculture seed testing manual (47).

Genetic Characteristics of Seeds. Considering the advances made in plant breeding during the last two decades, the genetic constitution of seed lots is, in many instances, the most important factor affecting ultimate productiveness. Certified seed is presently the best way of achieving genetic purity. It is a product of known ancestry, its genetical continuity being maintained through specified production procedures. Unfortunately most crop seed planted in the United States is not certified. In part, this is because the certification process is expensive; hence, the end product is more costly than ordinary seed. To some degree, it is because farmers have been able to obtain reasonably productive seed from other sources, and have not felt the need for varietal certification as keenly as, for example, some of the North European countries. In some instances, limited supplies of certified seed (principally of forage crops) have curtailed more widespread utilization.

The varietal identity (or purity) of seed several generations beyond certification is frequently conjectural; errors or misrepresentations as to designation are all too prevalent. It is true that seed laws require that the agronomic variety of seed, if indicated on the seed tag, be accurately designated—but this is more easily said than done. Varietal determination by ordinary analysis methods involving external morphological examination is frequently difficult or impossible.

From the seed control standpoint, certain laboratories maintain varietal control plantings. The Division of Seed Investigations of the New York Experiment Station has pioneered in this regard and the state of Virginia now possesses a strong program. Commercial seed lots, obtained in the course of routine inspection procedures, are planted in the field, and grown to maturity. Varietal identification (or verification) is subsequently made on the basis of mature plant characteristics. While this procedure may enable a seed control agency to take subsequent action against a dealer who has misbranded seed, it offers little direct protection to the consumer. Such seed has usually been sold and planted by the time the test is completed. Furthermore, field

plot procedures scarcely aid the seedsman or farmer in correctly labeling seed in the first place.

It is obvious, then, that varietal tests, which can be conducted on the seeds themselves and in connection with the conventional analytical examination, are much to be desired. A number of special tests for identifying varieties or varietal groups of certain crop species have been proposed (28). The methods in most instances are based upon differential physiological or chemical attributes of the seeds or seedlings of the varieties or varietal groups in question. Recent investigations have placed emphasis upon the simultaneous employment of several criteria so that varieties can be keyed out. Grabe (16 and 17), working with soybeans and oats, respectively, proposed a sequence of tests capable of distinguishing between the major agronomic strains of each of these two seed kinds. The characters employed included seed and seedling morphology, fluorescence examinations, and the differential response of varieties to different genetic strains of specific parasitic microorganisms. It was not possible to identify individual varieties on the basis of any one of these characters or responses. However, if the various methods were used in conjunction, the variety could be determined as in a conventional taxonomic treatment.

No doubt other techniques or criteria might have application in the development of laboratory variety testing. For example, paper chromatography or other analyses capable of detecting differences between chemical constituents could prove invaluable if suitable procedures were worked out and standardized. However, much remains to be done before varietal tests can be integrated into practice on a broad basis. Very few of the methods have been sufficiently refined to make precise, standardized distinctions feasible. Each major crop kind essentially requires the attention of a specialist. As seed laboratories are now constituted, not the least problem would be trained personnel. The constant release of new varieties and the concomitant fading out of older ones necessitates continuous alteration of tests and identification sequences. Furthermore, a precise definition of varieties of open-pollinated crops like alfalfa (*Medicago sativa*) is not possible. And, if multi-line varieties for small grains are adopted, laboratory diagnoses of the type employed by Grabe (17) will be inadequate.

Vigor. The word vigor has been employed with several connotations. My meaning is simply this: two seed lots having identical germinations in the laboratory may perform differently (one from the other) under field conditions. Vigor then connotes a difference in potential performance. For example, two lots of corn possess laboratory germinations of 90%. But the corn, if planted

Fig. 9. The cold test (a vigor test) for corn detects weak seed lots. Above: two corn seed lots appear about the same in a normal germination test made under favorable conditions. Below: the same two seed lots subsequent to cold test germination; the one to the right is shown to be capable of emerging under a wider variety of conditions.

early, may be subject to cold, wet soil. One of the seed lots may produce a satisfactory stand, perhaps 85% of the sprouts emerging in the field. But only 30% of the other seed lot emerges under identical field conditions (Fig. 9). This striking difference in performance between seed lots of identical potential germination is mediated primarily by the interrelationship between the seeds and soil microorganisms (29). Fully mature, physiologically vigorous, uninjured seeds are able to "resist" or grow away from soil microorganisms (e.g. *Pythium* spp.) to a greater degree than weaker or injured seeds.

It has been stated by some vigor test advocates that vigor can predict field stands whereas conventional laboratory tests are incapable of doing so. I noted earlier in this paper that laboratory germinations can scarcely be expected to predict field stands. And neither can vigor tests. No test will predict field performance *per se*. Field conditions are widely variable and as stated in the Bible, some seeds may fall on rocky ground, and others may be eaten by birds and fail to grow. These and similar variables are scarcely functions of the quality of the seed, nor do they relate to its evaluation. Vigor tests, then, are valuable supplements to ordinary germination tests but neither can be expected to account for the fate of all seeds in the field.

Vigor tests of varying sorts have been suggested for many seed kinds. However, the only performance evaluation widely used in the United States is the cold test for corn. The seed is planted at a temperature of about 50°C in, or in contact with, wet *Pythium* infested soil (9, 21, 45) and allowed to remain under these conditions for a week. Subsequent to this time, it is placed in a more favorable environment for the germination of the seeds. This test makes possible identification of weak seed lots, evaluation of seed treatment materials, and the rating of genetic characteristics of inbreds and hybrid combinations as to cold soil resistance.

Seed-borne Diseases. Certain plant pathogens are carried on or in seeds. In some instances, such parasites may not affect germination or early vigor, but developing along with the plant, subsequently lower the quality or quantity of yield. Obviously of two comparable seed lots, one free from a specific disease-inducing fungus or bacterium would be preferable to one harboring it. Testing procedures have been developed for a number of important plant diseases (1). In some instances, appropriate determinations are possible through seed or seedling symptoms; in other cases, culturing, and subsequent mycological identification is necessary.

Further Information

The above presents a skeleton outline of seed analysis methodology and discusses some of the problems besetting seed quality evaluation. It is a summary treatment only and several considerations are not treated, e.g. seed sampling, laboratory mixing and dividing, seed analysis tolerances, as well as various special tests. Seed analysis procedures are detailed in more extensive treatments (3, 27, 47).

Seed Laws and Laboratories; Seed Testing Organizations and Literature

Seed Laws. All of the states within the continental United States possess legislation regulating the movement of seed in commerce. In large part, these are labeling laws. They require that the seed be accurately labeled[4] as to purity and to germination. If the total weed seed content exceeds certain amounts (usually between 1 and 3%, depending upon the law), it is illegal to sell the seed.

[4] Within tolerances specified in the Rules for Seed Testing.

As previously indicated, these laws designate specific seed kinds as noxious. Usually noxious weeds are grouped into two categories: (1) primary noxious or prohibited, and (2) secondary noxious or restricted weed seeds. The occurrence of the first as seed contaminents renders sale of the crop seed illegal. The presence of the latter, within certain limits, does not limit distribution of the crop seed. Instead, the name and rate of occurrence per ounce or per pound of the crop seed must be indicated upon the seed tag. In other words, the purchaser must be warned; but he can buy the seed if he so chooses. If a wholesaler ships portions of certain seed lots to retail outlets in several states, each must be properly labeled in compliance with the laws of the respective state.

The Federal Seed Act acts as an adjunct to state laws. It has jurisdiction over seeds (1) moving in interstate commerce, and (2) entering the United States from other countries. With respect to the former, it supplements state laws, in effect requiring that seed from whatever source be labeled in compliance with the laws of the state in which it is exposed for sale.

Seed Laboratories. Seed tests are made by industrial laboratories, independent commercial laboratories, and state and federal government laboratories.

Most of the larger seed firms possess their own seed laboratories. The nature of the tests conducted depends upon the requirements of the company; analyses may be made in connection with the purchase and sale of seeds, during processing, and as a means of providing label information for retail outlets.

Independent commercial laboratories are patronized especially by smaller seed companies which do not possess sufficient volume to afford their own testing service. However, many of these laboratories also attract considerable business from major firms who desire to double-check their own analyses.

State seed laboratories are varied in administrative structure and responsibilities. In some instances, they are associated with state departments of agriculture and engage primarily in seed law enforcement testing. Service testing for farmers and industry is frequently conducted, but is usually a secondary objective. Other state laboratories, affiliated with the land-grant institutions in their respective states, emphasize service testing, especially for farmers, and, in some instances, seed education and research. The several federal seed laboratories are concerned entirely with law enforcement and do no service testing.

Seed Testing Organizations. *Association of Official Seed Analysts.* This is an organization of some 65 state and federal seed laboratories in the United States and Canada. It publishes an annual "Proceedings" which contains technical papers relating to seed technology as well as a quarterly News Letter and "Contributions to a Handbook on Seed Testing." The latter two items are mimeographed.

Society of Commercial Seed Technologists. This society includes analysts associated with seed companies and independent commercial seed laboratories. Publication is limited to a quarterly News Letter.

International Seed Testing Association. The membership represents federal government laboratories throughout much of the world. Active participation is largely limited to North European and North American countries. The official organ of the Association is the Comptes Rendus de l'Association Internationale d'Essais de Semences which contains technical articles in French, English and German.

Seed Technology Literature. Literature relating to seed physiology, morphology, and taxonomy may be found in a variety of botanical and agricultural jour-

nals. Papers concerning seed testing *per se* are largely restricted to the Proceedings of the Association of Official Seed Analysts, and the Comptes Rendus de l'Association Internationale d'Essais de Semences. A special Golden Jubilee Publication of the Association of Official Seed Analysts, "Fifty Years of Seed Testing" (2) contains many useful summary and review papers. United States published books and reviews concerning seed testing include the following: (27, 42, 44, 47). Seed physiology is treated by Crocker and Barton (8) and Baldwin (4).

Seed Quality Evaluation and Agriculture

The Seed Production and Marketing Industry. Seed production is becoming an increasingly specialized technology. Mechanization of harvesting and processing has required increased emphasis upon quality control. Seeds are frequently tested subsequent to harvest, during processing and blending, and at intervals in storage.

With respect to marketing procedures, seeds are usually bought and sold on a quality basis as determined by seed analysis. When a seed lot changes hands, it is frequently retested (as a check) by the purchaser. In addition, the final seed analysis test provides the seedsman with the labeling information required by state and federal laws when seed is exposed for sale on the retail market.

The Seed Consumer. It is perhaps possible for a home owner to regard a stand failure of vegetables or flowers due to poor seed as a loss equivalent to the purchase price of the seed. This is not the case with the farmer. His purchase of seed is an investment bearing directly upon his income for the following year. Low quality seed (whether as to germination, genetic characteristics, weed seed contents, etc.) is a limiting factor which cannot be overcome by the best production methods.

Fortunately, the purchaser of seed possesses at least a partial guide. He is protected not only by certain prohibitions, but by the availability of label information which (assuming he makes use of it) provides an evaluation of the quality of the seed. Differential quality levels as indicated on the label are often considerably more significant than different prides. One way of equating purity and germination with price is through use of the "pure live seed"—the product of the purity and the germination. For example, if a seed lot has an 80% purity and a 70% germination, the pure live seed is 56%. From a sack of 100 pounds of seed, only 56 pounds are capable of producing normal seedlings. At $30.00 a 100 pounds, this seed is then more expensive than seed priced at $40.00 but with a pure live seed content of 80%.

The pure-live seed index is an approximation. Its validity is based on the premise that live and dead seeds are of equivalent weight. This is not necessarily true. Dead or weak seeds (especially immature ones) are usually lighter than viable ones. Nevertheless, the purity-germination product possesses commercial usefulness. It reduces two variables to a single figure and allows consumers and dealers to compare seed lots in a linear sequence.

An Assessment. Although, as outlined in the above section, the application of seed quality evaluation plays a vital role for both producer and consumer, its potentialities have not been tapped. Seed technology has not developed at a rate commensurate with other phases of economic botany and agricultural science. For example, careful research attention is given to soils as they affect potential plant growth. Methods of crop production have received detailed study and improved practices have been taken up. Plant breeding is a major area of agricultural science investigation. But the area of seed science and technology has by comparison made relatively meager prog-

ress. L. N. Wise (49) has stated, "By actual count one state agricultural experiment station has 30 soil scientists working on over a hundred soil research projects. The budget for this could not be less than one quarter of a million dollars per year. Since no work is in progress on seed technology, there is no need for a budget. In this same state, there are three extension soil specialists disseminating soil research information to the county agents and to the farmers. There being no seed technology information to disseminate, it is not surprising that there are no extension seed specialists."

At least some of the reasons for this situation are not hard to discern. One of these is that the United States with its chronic surpluses has never experienced a direct and critical need for quality seeds. By contrast, food shortages in several North European countries have been directly correlated with seed inventories; and these countries are not much more quality conscious than the United States. For example, traditional seed sources were cut off from the Scandinavian countries during the first world war. Food deficiencies ensued as a consequence of insufficient seed for planting. After the war, poor quality seed from a wide variety of sources was "dumped" into these countries. This seed was largely of varieties which were not adapted to the climate. The consequences were clearly discernible in lower crop yields. Vigorous government action instituting rigid quality control and stimulating domestic production was undertaken. This sound program paid off during World War II and seeds were not a limiting factor in the maintenance of food production.

Another reason for the peculiar position of seed technology in the United States: seed science had its birth on the European continent essentially as a consequence of the classic researches of Nobbe (41). Its migration to the Americas was in large part via the legal route as a consequence of the seed-borne spread of noxious weeds. Hence, an attempt to solve the problem through legislation: test the seed for noxious weeds and prohibit the sale of contaminated stocks. Government seed laboratories and seed specialist personnel are still to a large extent associated with law enforcement agencies. In many states, outstanding control programs as well as cooperative endeavors between industry and the state have been maintained.

Credit should be given to those individuals who direct or have directed seed control programs. But research and education do not fall within the province of responsibilities of control laboratories. And, unfortunately, only a few of our land-grant institutions have active seed quality programs. There has been little money for research. Most investigations have been conducted by a few devoted individuals whose principal responsibilities are elsewhere. Perhaps there is now an upward trend. The recent emergence of new and strong programs in certain agricultural institutions and in the initiation of U.S.D.A.-sponsored regional projects give promise for the future.

But research is not enough. New methods must be put into practice. Furthermore, improved testing will go for naught if agriculture renders only lip service to the use of quality seed. Seeder box surveys still show the wide prevalence of noxious weeds in agricultural seed as it goes into the soil. A number of crop kinds (notably small grains, soybeans, and small-seeded legumes) are largely homegrown and untested. Farmers often blame stand failures on anything except the seed. For the most part, they purchase seed by the price tag rather than the label information. Since seed laws are in large part labeling laws, their purposes are to a large extent frustrated without commensurate acceptance by seed consumers (10, 11).

Seed quality evaluation and control is

only one phase of seed science and technology. In the broader sense, it is an area embracing likewise seed production, harvesting, processing, treatment, and storage. Future progress in seed science demands better coordination of objectives and efforts between these disciplines than has previously existed.

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The Freezing Preservation of Vegetables[1]

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Introduction

The commercial preservation of foods and food products began in the United States with the freezing of fish and poultry in 1865, the freezing of small fruits in 1905 and the freezing of vegetables in 1929. The earliest year for which pack statistics for frozen fruit were reported was 1908, when about 10,000 pounds of berries were frozen. The commercial freezing of fruit and fruit products developed slowly at first and increased appreciably only in 1936 and later. Production reached 525 million pounds in 1946, rose to 695 million pounds in 1956, decreased to 620 million pounds in 1959, but reached a maximum of 697 millions in 1960. The commercial production of vegetables started later and at first developed more slowly. The pack amounted to 7 million pounds in 1937 (less than 9% of the frozen fruit pack), reached 450 million pounds in 1946 (86% of the frozen fruit pack), 1,626,000,000 lbs. in 1959 (26.3% of the frozen fruit pack), and 1,959,000,000 in 1960 (281% of the frozen fruit pack.)

The production of frozen vegetables increased much more rapidly during the period 1947-1955, than did that of frozen fruit. The frozen food industry is second to the dry food industry in its use of folding cartons for packaging. A recent survey indicated that the frozen food industry annually uses 3,600 millions of cartons in comparison with 10,200 millions used by the dry food industry. The distribution of use is shown in Table 1. This indicates that 125 plants of 555 were processing vegetables in 1960. The production and sales of frozen foods by category in 1959 are shown in Table 2. The frozen vegetable pack in 1959 amounted to 25% of the total frozen food pack, and its sales value was 18% of the total.

The total quantity of vegetables frozen is small in comparison with that grown for sale as fresh and processed. Preservation by freezing, however, has become a highly important outlet for a number of individual crops. Vegetables such as cauliflower, broccoli and brussels sprouts are commercially processed only by freezing and considerable quantities of others are being processed by both canning and freezing. Freezing has become a highly important outlet for a number of individual crops. Sixty-six per cent of the crop of brussels sprouts, more than 50% of the green lima beans, 25% of cauliflower and 10% of asparagus production were frozen in 1952 (14). The utilization of the commercial vegetable crop for freezing in 1959 is shown in Table 3, which indicates that about 10% of the sweet corn and carrot crop were frozen, about 15% of the green bean crop, over 25% of the asparagus and cauliflower crop, 50% of the spinach and kale crop and

TABLE 1.

CARTON CONSUMPTION IN FROZEN FOOD INDUSTRY[1]

	Plants	Cartons (millions)
Convenience foods	150	2,110
Fruits and juices	125	20
Potato products	20	200
Seafoods	120	20
Vegetables	105	1,200
Other frozen foods	35	50
Total	555	3,600

[1]From Market Research Report Canner/Packer, June 1961.

[1]Received for publication 23 Aug., 1961.

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TABLE 2.

PRODUCTION AND SALES OF FROZEN FOODS BY CATEGORY IN 1959[1]

	Production in Pounds	Sales at Retail Value
Fruits	618,000,000	$ 160,000,000
Fruit Juice Concentrates	1,096,000,000	438,000,000
Meat	300,000,000	240,000,000
Poultry	1,747,000,000	609,000,000
Prepared Foods and Specialties	700,000,000	525,000,000
Seafoods	478,000,000	282,000,000
Vegetables	1,626,000,000	495,000,000
Totals	6,565,000,000	2,749,000,000

[1]From H. L. Franklin. 100 Leading metropolitan county frozen food markets. QFF Retail Frozen Food Marketing Guide, Quick Frozen Foods *23* (8), 163-194 (1961).

over half the green lima bean, broccoli and brussels sprouts crop were frozen. The annual per capita consumption of frozen vegetables increased from 0.4 pound in 1937 to 8.87 pounds in 1959. The consumption of frozen vegetables in 1959 amounted to about 9% of the total fresh (99.6 pounds).

In the early development of the industry more peas were frozen than any other vegetable. In 1937, the order of production was peas, lima beans, snap beans, asparagus and corn, spinach and broccoli. Peas and carrots were packed in appreciable quantities first in 1939, brussels sprouts and cauliflower in 1940, carrots in 1941, succotash in 1945, and potato products (chiefly French fried) in 1947. Peas continued to lead until 1959 when they were surpassed by potato products. The frozen potato products industry is reported to have begun in 1945 in Maine and since then production of frozen French fries and other frozen potato products has increased steadily from an initial pack of 3.5 millions of pounds to over 550 millions in 1959. About 9 million bushels of potatoes were used from the 1956 crop for processing into frozen potato products. This represented 13.6% of all potatoes used in food processing, excluding pre-

TABLE 3.

UTILIZATION OF COMMERCIAL FRESH VEGETABLE CROP FOR FREEZING, 1959

Commodity	Vegetable Production Fresh Tons[1]	Frozen Vegetable Production millions pounds[1]	equivalent farm weight—tons[2]	% Crop frozen
Asparagus	118,300	32.7	32,700	27.7
Beans, green lima	96,500	114.0	63,300	65.6
Beans, snap	568,900	149.0	92,300	16.2
Broccoli	113,000	103.2	93,800	83.0
Brussels sprouts	29,500	38.7	35,200	100.0 (?)
Carrots	680,800	55.5	55,500	8.2
Cauliflower	200,100	33.6	57,000	28.5
Corn, sweet	2,229,000	121.0	261,800	11.8
Kale	8,800	4.4	4,400	50.0
Peas, green	476,600	305.0	172,000	36.1
Potatoes	12,164,000	371.0	371,000	3.6
Spinach	230,000	121.9	110,800	48.2

[1]From U. S. Dept. Agr. Agricultural Statistics 1960. U.S. Govt. Printing Office, Washington, D. C., 1961. 633 p.

[2]Calculated from conversion factors in U. S. Dept. Agr., Production and Marketing Admin. Conversion factors and weights and measures for agricultural commodities and their products May 1952, 96 p. See Table 64, p. 75.

peeled potatoes, but less than 3% of all potatoes used for food (92). The commercial production of frozen vegetables in 1960 by kind is shown in Table 4. About 75% of the pack was composed of potatoes, green peas, green and wax beans, green lima beans, sweet corn, spinach and carrots.

Of the white potato products frozen in 1960, 21% were produced in the eastern United States (chiefly Maine) and 79% in the western United States (Idaho). Of the green peas frozen, 18% were produced in the eastern and southern regions (Maine, New York, New Jersey and Maryland), 7% in the midwest (Minnesota, Wisconsin) and 75% in the west (Washington, Oregon and Utah). Of the green beans 60% were frozen in the east (New York, New Jersey, Maryland) and 35% in the west (Washington and Oregon). Of the green lima beans, 24% were frozen in New Jersey, Maryland and New York and 73% in California. Of the sweet corn, 25% was frozen in east and south (New York, Maine, Maryland), 18% in the midwest (Minnesota and Indiana) and 57% in the west (Washington and Oregon). Of the spinach 38% was frozen in east and south (New Jersey, New York, Maryland) and 62% in the west (California, Washington and Oregon). Asparagus is frozen principally in California, Washington, Oregon, New Jersey, Maryland and New York. Broccoli, brussels sprouts and cauliflower are frozen chiefly in California and the Pacific Northwest. Reed (82), in a survey of the Pacific Coast frozen fruit and vegetable processing industry made in 1955, reported that the Pacific Coast States produce approximately 70% of the green peas, 65% of the lima beans, 40% of the snap and wax beans.

In Washington the greatest concentration of freezing plants is in the northwest section of the state along Puget Sound and in the Yakima Valley. Oregon has two principal areas of concentration—the Willamette Valley of western Oregon and the Pendleton area of northeastern

TABLE 4.

COMMERCIAL PRODUCTION OF FROZEN VEGETABLES IN 1960.

	(millions of pounds)	% of Total Crop
Potato products	551.4	27.7
Peas, green	295.2	14.8
Beans, green and wax	159.7	8.0
Bean, green lima	147.6	7.4
Corn, sweet	141.8	7.2
Spinach	118.6	6.0
Carrots	72.1	3.6
Cauliflower	48.7	2.5
Mixed vegetables	46.1	2.3
Asparagus	40.0	2.0
Brussels sprouts	39.3	2.0
Peas and carrots	27.9	1.4
Pumpkin and squash	23.4	1.2
Okra	18.0	0.9
Turnip greens	17.2	0.9
Succotash	7.4	0.4
Rhubarb	7.2	0.4
Kale	4.5	0.2
Miscellaneous	124.4	6.3
Total	1,190.5	

From National Association Frozen Food Packers. First Complete Figures on 1960 Production. Quick Frozen Foods *23* (10), 65-74 (1961).

Oregon. In California the largest concentration of freezer plants is in the Santa Clara, Pajaro, and Salinas Valleys; next in importance is the area bounded on the north by Yuba City and on the south by Sanger in the Central Valley; and finally the south coastal area from San Luis Obispo to Los Angeles.

The spectacular increase in consumer acceptance of frozen vegetables and other frozen foods in recent years is attributed to their convenience for use, their fine flavor and appearance when served, and their relatively high nutritive value and safety (12). The techniques now available and used by producers and packers protect color, flavor, and nutritive value as no other means of preservation can do. In good commercial practice, selected varieties of vegetables are grown under suitable climatic and soil conditions, harvested at prime maturity (often with delay of only 3 or 4 hours between harvesting and freezing operations), promptly transported to freezing plant, carefully sorted, trimmed and prepared for freezing, promptly frozen before or after packaging, and stored and distributed at a temperature low enough to prevent undesirable changes in color, flavor and nutritive value caused either by chemical reactions of the naturally occurring thermolabile constituents or by the metabolic activity of surviving micro-organisms. The scientifir bases for the modern industrial practices were developed during the early period of 1928 to 1936 and their application and development has continued.

Historical Developments and Recent Trends

The earlier historical development was discussed by Diehl and Havighorst (17), Joslyn and Diehl (47), and Tressler and Evers (96). Until 1928 the preservation of vegetables by freezing even under laboratory conditions was not successful because of undesirable changes in color and flavor. Joslyn and Cruess (45) reported successful retention of color and flavor at 0°F by blanching prior to freezing and proposed the retail distribution of frozen vegetables in paperboard containers. At about the same time Kohman (53) reported that freezing resulted in the development of the same type of off-flavors as mechanical bruising or storage at low oxygen tension. He also found that cooking prior to freezing prevented the development of these off-flavors. These observations were confirmed by Tressler (95), Morris and Barker (72), Diehl et al. (16) and others. With the establishment of the necessity to inactivate tissue enzymes by heat prior to freezing, the development of proper conditions for blanching and its application to various vegetables followed.

During the period of 1929-1936, the early investigators laid the foundation for future expansion of the industry by testing the behavior of different kinds and varieties of vegetables to freezing, freezing storage and subsequent thawing. On the basis of this experience the adaptability of different varieties of vegetables grown under different soil and climatic conditions was determined. In this period also, considerable attention was devoted to the microbiological aspects of preservation freezing, particularly to determine the conditions under which frozen vegetables would support growth of toxin-forming bacteria which might result in food intoxication and the viability of bacteria that might be responsible for food-borne infections. Packaging, freezing, storage, distribution and marketing problems were solved by the pioneer frozen food packers. Mechanization of processing and handling methods were developed by the industry and by machinery manufacturers. The initial attempts to distribute to retail outlets were not successful and were replaced by distribution to institution channels where controls over storage and preparation could be made more readily and effec-

tively. Gradually the institutional channels (hotels, restaurants, hospitals, clubs) and finally the retail outlets were exploited. Economical methods of refrigerated storage and of distribution to retailers were developed, as were refrigerated cases for distribution by retailers. Both retailers and consumers were instructed in the proper use of the frozen product. Then followed a rapid increase in processing and packaging techniques. Standards of grade for various frozen vegetables were introduced by the United States Department of Agriculture, first in the Processed Products Standardization and Inspection Branch of the Fruit and Vegetable Division of the Agricultural Marketing Administration of the U. S. Department of Agriculture, which later was changed to the Agricultural Marketing Service. Continuous in-plant inspection as well as lot inspection was practiced to assure the consumer of high quality. The quality of much of the frozen fruit and vegetable pack reached high levels of development by 1941.

During the war years 1942-1945 and immediately following the war sales of frozen foods increased rapidly because they were not rationed and canned foods were scarce. During this period there was a noticeable decrease in quality because of a large, unfilled consumer demand and competition for the limited quantity of available raw produce. The following additional factors also contributed to this relaxation of quality control from field to plant, within the plant and from plant to consumer:

Shortages of experienced labor; lack of machinery for orchard cultivation and for preparation, processing, and packaging; shortage of packaging materials; limitations in availability of refrigeration facilities for storage and distribution; pressure on every packer to process as much tonnage as could be handled by his plant; the entry of new packers into the field. Not all these were inexperienced. Some were skilled food processors from other fields. But some had little or no knowledge of the fundamentals by which high-quality and low-cost production of frozen foods could be achieved.

During the period of 1936-1940, investigations on the nutrition value of frozen foods were initiated at the Department of Horticultural Manufactures (now the Department of Food Technology) of the Massachusetts State College at Amherst by Dr. Carl R. Fellers and his staff and at the Division of Chemistry (now the Department of Food Science and Technology) of the New York Agricultural Experiment Station at Geneva by Dr. Donald K. Tressler and his staff. These investigations were expanded and continued there and elsewhere to obtain information on the losses of vitamins and other nutrients which may occur during the preparation, freezing, freezing storage and cooking of frozen foods. More recently the National Association of Frozen Food Packers sponsored a comprehensive program at the Wisconsin Alumni Research Foundation. Data on the content of nine vitamins, four minerals and proximate composition of 14 frozen fruit products, 7 frozen juice products, and 31 frozen vegetable products from representative commercial plants were obtained, Burger et al. (11), and in addition the effects of storage condition on nutrients in frozen green beans, peas, orange juice, and strawberries were investigated (Derse and Teply, 15).

The industry began to be concerned over the serious deterioration in quality that occurred between products shipped out of the freezing plant and those sold at the retail level. Comparative cut-outs of frozen food samples procured at the freezer plant and those obtained at retail outlets throughout the United States indicated serious deterioration in quality because of failure to store the products at a sufficiently low temperature particu-

larly in the open self-serve frozen food display cases. It had been established that 0°F was the maximum temperature at which frozen foods should be held but surveys of commercial storage and distribution showed that higher temperatures were the rule rather than the exception. While some information was available, comprehensive data were lacking on differences in deterioration of frozen foods held at various temperatures. Upon request of the industry in 1948, the U.S.D.A. Western Regional Research Laboratory at Albany, Calif. undertook an extensive study of the temperature-time tolerance of frozen foods. Since the initial publication of the first article in this series in 1957 (Van Arsdel, 97), over 22 original contributions have been published to date. Frozen foods were found to be remarkably sensitive to temperature increase and the storage life at various temperature conditions was established for number of representative commercially packed foods.

In recent years considerable attention has been given to the investigation of the chemistry of changes in color and flavor in under-balanced vegetables and the establishment of proper conditions of blanching. The enzymes actually involved in off-flavor formation, the substrates acted upon, the factors influencing rate and extent of chemical change, and the chemical components responsible for off-flavor have not been determined although there is reasonable evidence that lipide oxidation may be a major factor (Lee, 57). There is still no general agreement as to the utility of control of the blanching process by the degree of inactivation of plant peroxidase or catalase activity and investigations of the more generally applicable peroxidase assay technique continue. The physical changes that occur as a result of ice formation and which are reflected in changes in texture on freezing and subsequent thawing still remain to be solved. The knowledge being developed on the general principles of freezing and freezing injury in cellular materials (Precht et al., 77; Meryman, 69) has still be be evaluated and applied to freezing of vegetables.

Although the general factors determining varietal adaptability to freezing were established in the earlier and subsequent investigations for the most part these were based largely on empirical experience rather than on exact scientific knowledge. Objective evaluation of quality for processing and the influence of cultural conditions, and post harvest physiological changes on the varietal suitability for preservation by freezing remains to be developed, (Tompkins, 94). The harvesting, handling, preparation for freezing, and freezing have been largely mechanized (Reed, 82), and this has resulted in relatively small increases in freezing costs in spite of increases in prices of the factors involved in freezing (French, 23). Increase in yields of vegetables through improvements in culture, and decrease in labor costs through improvements in organization, scale of operation, management and mechanization have combined to result in relatively small change in price for raw materials to processors. Freezing costs in 1947-1959 increased at first in the same rate as production costs until 1952. Since that time cost per unit of farm vegetable production have decreased while processing costs have increased slightly.

Present Industrial Practices

The vegetables used in freezing operation are normally obtained from contracted or processor owned acreage. The processor-owned acreage is limited and is more extensive in eastern United States than in the Pacific Coast States. Most of the vegetables frozen are contracted for on an acreage basis prior to the processing season. While in the early development of the industry there was limited control of quality and coordination of field and processing operations (Joslyn,

37), today a high percentage of processors furnish technical advice and specify varieties of seeds, fertilization and harvesting (Reed, 82). In order to control quality, coordinate field and processing operations, and assure raw product supplies the processors specify or furnish seeds, indicate planting time in particular areas, specify or provide fertilizers, pesticides and fungicides, chemicals for weed control, and may harvest the crop. Crops requiring close supervision, with respect to quality as affected by maturity and rapidity of handling, such as lima beans, green peas, and spinach, usually are harvested by the processor. This practice also gives the processor a better integration and coordination of field and plant operations by avoiding either delays in receipt of raw materials necessitating costly layoffs of plant labor or receipt of raw materials in quantities beyond the peak processing capacity of the plant.

To assure an adequate and dependable supply of freshly harvested vegetables during the freezing season and its transport to the freezing plant in quantities and at a rate that would allow prompt, efficient and orderly processing requires careful planning by the plant superintendent and field personnel. In order to achieve staggered harvesting of the acreage planted, use is made of heat summation in scheduling successive plantings and of varieties and strains differing in period of time required for maturation (Seaton, 84). The probable harvesting maturity for a particular area, as predicted by heat unit summation, is checked by periodic inspection and field testing. The vegetables are harvested at the time fixed as rapidly as possible. Harvesting of most commercially grown vegetables is now mechanized to reduce costs and particular care is taken to avoid mechanical damage during harvesting or delay between harvesting and processing. Vegetables such as green peas and lima beans are cut mechanically, and the vines are automatically loaded into trucks for hauling to viner stations or are cut and vined by the use of special combinations of harvesters and field viners. Spinach may also be cut mechanically. Where hand cutting is necessary this is carefully organized to reduce man-hours of labor required by work simplification and other means. The cut vegetables such as brussels sprouts, broccoli and cauliflower are loaded directly into tote bins, field trucks, or other transportable field containers for prompt dispatch to the processing plant.

Vegetables are loaded in the field either into containers such as bins (approximately 4 feet x 4 feet x 4 feet), baskets (7 feet x 4 feet x 4 feet), trailers, tanks or dump trucks for bulk handling operations or into big boxes which are palletized and loaded into trucks by fork-lift-trucks. Bulk hauling is used for products that can withstand such handling without bruising or shattering. All vegetables except asparagus are received in some plants in bulk containers. Lug boxes or crates are widely used in receiving asparagus, broccoli, and brussels sprouts.

The vegetables after weighing, inspection and grading are automatically unloaded by dumping from bins and tanks while trailers are mechanically tip dumped or hand forked. While in most plants fragile commodities such as asparagus, broccoli and brussels sprouts are dumped manually, methods have been developed for bulk handling and mechanical dumping or unloading even of these vegetables. Materials handling both out of plant and in-plant have been developed and are widely used in freezing plants as part of the rapidly rising trend of mechanization. Automatic dumping of raw products, mechanical lift trucks for receiving and in-plant transportation of supplies, powered hand trucks and pallett handling are used to reduce labor costs. Continuous conveyor systems such as belt, mesh, roller, pipe, flume, and other conveyors are widely applied and

automatic machines for trimming, stemming, peeling, cutting, chopping, blanching, sorting, filling, continuous packaging, wrapping, and automatic continuous and multi-plate freezers are in use.

Immediately on receipt at the processing plant, the vegetables are weighed and inspected and graded for quality so that the grower may be paid. A representative sample of each load received is taken either by automatic sampling during unloading after weighing or by lot sampling. Its size and quality grade is assessed by determination of sieve size, maturity and tenderness by tenderometer, succulometer, shear press, or other device.

In-plant the vegetables are subjected first to sorting and cleansing operations which vary with the type of vegetable being processed. Green peas and lima beans may be cut as vines in the field, fed into viners to separate seeds from pods and vine at harvesting or at field or factory vinery station, and delivered to the plant either before or after dry-cleaning. The peas from the viners may be dry cleaned by passage over shaker screens vibrating horizontally with an upward draft of air to remove leaves, particles of vine and other foreign matter. Root vegetables are dry cleaned by passage through specially designed rolling screen or vibrating screens and broccoli and brussels sprouts also are freed of contaminating dirt, loose leaves and other foreign matter by suitable shaker conveyors. Leafy vegetables such as spinach are dry-cleaned first before washing. The raw vegetables are then sorted over inspection belts, washed and cleaned in a variety of specially designed units. Green peas are washed in cool running water, conveyed by flumes into froth cleaners where nightshade berries and other foreign matter that can not be separated by convention clipper cleaners are removed by froth flotation, washed in rod reel washers. Specially devised soaker washers are used to clean other vegetables. Root vegetables are peeled automatically in steam pressure peelers, cauliflower is trimmed and cut, brussels sprouts are trimmed to remove outer leaves, asparagus is cut to length, green beans pass through snappers to remove ends and are then cut into suitable lengths either cross cut or French cut. Lima beans, peas, and green beans are size graded automatically and asparagus is manually size graded. Cut vegetables like carrots or potatoes are graded to separate off-cuts and chaff. Corn on the cob is automatically cut, husked, and trimmed to remove silk and other tissue. The cobs are sorted, and washed. Cut corn may be prepared by cutting before blanching, after blanching on the cob or even after freezing.

The sorted, cleaned, washed and prepared vegetables are then conveyed to blanchers when they are automatically blanched at temperatures from 190°F to 212°F for 1½ minutes to 8 minutes depending on the type and size of vegetable.

The methods of preparation for freezing vary according to the requirements of the product, degree of mechanization, plant organization, rate of output, plant layout, etc. As a general rule vegetables may be classified into free-flowing items such as lima beans, green peas and corn; or hand-packed commodities such as broccoli, asparagus, brussels sprouts, cauliflower and spinach. Free flowing commodities are normally moved by hydraulic pumps and flumes through froth cleaners, quality separators, pneumatic cleaners and blancher to automatic fillers. Hand-packed commodities require a large labor force in most stages of operation but mechanical devices for removing the stem end of brussels sprouts, for shattering heads of cauliflower into individual curds, for cutting asparagus and broccoli are available and are being used.

Blanching or scalding in steam is preferred to water blanching to reduce loss of soluble constituents. Immediately after blanching the hot tissue is cooled as

rapidly as possible to room temperature by water spray, water flumes or air cooling. Particularly care is taken to minimize exposure of the hot tissue to water in order to reduce losses of soluble constituents by leaching.

After blanching and chilling, green peas and lima beans are quality graded in specially designed brine quality grader in which the starchy mature peas and beans separate by sinking and the tender immature seeds float. After quality grading the seed vegetables are washed and dewatered. Other vegetables after blanching and chilling are dewatered to remove as much as possible of the adherent and occluded water.

The commodities that are hand-filled, such as asparagus spears, broccoli spears, leaf spinach and cauliflower are size graded and sorted for quality and placed in retail or institutional size cartons by hand. The cartons may be formed by hand or mechanically. Free-flowing items such as green peas, lima beans, chopped spinach, chopped broccoli, diced carrots are packaged in automatic continuous packaging machines which feeds, opens, fills, and closes retail or small institution sized cartons. The weighing and closing operation varies with method of filling and type of container. For hand-filled items in manually formed containers, each package is removed from the packing line conveyor, weighed, and product is added or removed to make weight. The carton is closed manually and returned to the conveyor for transfer to a wrapping machine. For machine-filled commodities the filler is mechanically supplied with cartons from an automatic carton-forming machine, these are filled and closed automatically, weighed on a sample basis and then wrapped automatically.

The vegetables usually are frozen after packaging either in an air blast freezer or contact-plate freezer, partially or fully automatic. Products like asparagus, broccoli spears, and cauliflower are always frozen after packaging. Green peas and beans, however, may be frozen on trays on conveyors prior to freezing. This is true also for mixed vegetables such as peas, corn, and succotash, etc. Vegetables frozen in bulk before packaging must either be frozen in specially devised shaker screens to prevent clinging or be conveyed through cluster-breakers before filling.

The vegetables after freezing and packaging are packed into fiber board cases for storage and shipment. Casing may be mechanized in larger plants or semi automatic in smaller plants.

A typical flow sheet for frozen peas is shown in Figure 1.

Present Status and Unsolved Problems

Raw Material Aspects. The importance of varietal adaptability to preservation by freezing was recognized by the early investigators shortly after the demonstration of noticeable differences in response to freezing of the various commercially available vegetables (Joslyn and Diehl, 47). During the period of 1930-1940 the varietal characteristics desirable for the more commercially important vegetables were established by initial studies on replicated row plants and later on small acreage plants by investigators of the U.S.D.A. at its various field stations in cooperation with various State Agricultural Experiment Stations. These studies have been continued and greatly expanded since 1946 and currently more work is being done in evaluating vegetable varieties for freezing than on other objectives except the time-temperature tolerance studies. Several regional laboratories and stations of the Agricultural Research Service of the U.S.D.A., of some fifteen State Agricultural Experiment Stations (particularly California, Oregon, Washington, Maryland, Michigan, Ohio, New York, Florida, Georgia, and Texas), the larger frozen food packers and the leading seed companies have active programs in this

FIGURE 1. FLOW SHEET FOR FREEZING GREEN PEAS, INDICATING MAJOR UNIT OPERATIONS.

Harvesting

Mowing pea vines, raking cut vines into rows, side row loader for transport or conveying to viner. 100 tons of cut vines yield an average of 20 tons hulled peas. Usual yield of peas is 1500-2000 lbs. hulled peas per acre.

Vining

Transport harvested peas to field viner station, to central viner station, to viner station at processing plant, or vining in mobile field combination harvester-viners. At viner the peas are separated from vines and hulls by beater blades rotating counter to perforated cylinders which break the vines, open the hulls and pea seeds pass thru holes in the screen, drop onto conveyor aprons where additional separation occurs as seeds roll whole leaf and hull particles adhere to surface and discharge at edge. Viners have capacity of 0.5 ton peas per hour, the beater blades are adjusted in pitch and speed of rotation to obtain maximum yield of peas with minimum bruising.

Transport

The vined peas may be cleaned at viner station or transported to processing plant. Peas must be handled quickly to prevent flavor change and toughening of pea seeds caused by enzymes present in vine juices that coat peas, and to avoid microbial growth.

Weighing and Sample Grading

On receipt at plant, the loads are weighed, and a representative sample of each load is graded for size, maturity and tenderness.

Dry Cleaning

Pieces of hulls, vines and foreign matter including soil and stones are separated by passage through special cleaners where by combination of vibrating screening and air blast much of this foreign matter is removed. Cleaners of capacity up to 6 tons per hour are used and the average loss in cleaning is 14%. Thus from each 100 tons of vined peas there are obtained 86 tons of cleaned peas.

Washing

Immediately after dry cleaning the peas are subjected to a series of washing operations depending on the particular problems encountered. Washing is carried out generally by a combination of soaking to loosen adherent dirt and spray washing in rotating rod-reel washers. Particular care is taken to remove all viner juice. Special washers may be used to separate thistles and to remove nightshade berries and other foreign matter having the same size and specific gravity as peas. For the latter purpose froth flotation washers have been introduced in which separation is based on differences in surface properties.

Dewatering

The peas during washing and cleaning operations are conveyed in flumes or by hydraulic pumps and before sorting are separated in rotary screen dewatering machines.

Sorting

Preliminary sorting while passing before inspectors on conveyor picking belts.

Size-Grading

Mechanical size grading in automatic sievers.

Blanching

Peas are usually blanched in hot water blanchers where they are heated to 190-210°F and held at this temperature ½ to 1½ min. Hot water blanching is used because of its better cleansing action in removing off-flavors due to viner juice. Steam blanching is preferred because leaching losses (sugars, water soluable vitamins, etc.) are less.

Chilling

Immediately after blanching the hot peas are cooled to room temperature by passing under water sprays and through flumes of running cool water. Particular care has to be taken to

reduce contact with water to a minimum to avoid excessive leaching losses. Air cooling is being introduced as a possible cooling medium.

Quality Grading

The more mature starchy peas are separated from the tender green peas by flotation separation in specially devised and operated salt brine separators in which the starchy peas of heavier specific gravity settle and the immature peas either remain suspended or float. Brine grading is more efficient after blanching because air and other gases in the pea tissue which tend to buoy up the peas are removed. Sometimes quality grading is carried out both before and after blanching as is done with green lima beans. After brine grading, the peas are separated from the brine by screening and washed with clean water.

Dewatering

The graded peas are flumed or conveyed to filling stations and are separated from water by passage through dewatering reels or other devices to avoid packaging with excess moisture. The loss in weight between dry-cleaning and all subsequent washing and sorting operations amounts to 2 to 2.5%. Thus from 100 tons of dry-cleaned peas about 97.5 tons of washed, sorted, blanched and graded peas are recovered.

Filling and Packaging

The prepared peas may be frozen before or after packaging. The usual practice for the best grades is to fill into self-locking paraffined cartons that are filled, closed and then overwrapped with moisture-, vapor-proof, heat-sealing wrappers. Of the 1960 pack of 295.23 million pounds, 39.3% were packaged in retail containers less than 1 lb., largely in 10 oz. size: 13.0% were packaged in institution size containers of 10 lbs. and less; and the remainder of 47.7% in large-sized containers of over 10 lbs.; of the latter, 41% were in 50 pound containers.

Freezing

The packaged peas are frozen either in contact-plate freezers or in air-blast freezers. Freezing may be carried out in processing plants where the peas are received, prepared and packaged or transported to commercial cold storage warehouses for freezing and storage. On the Pacific Coast the latter is more common, about 70% of the processors depending for freezing and storage upon commercial plants. In air-blast freezers the product is exposed to a high velocity air blast at a temperature between —20 and —40°F in column, belt tunnel or tray tunnel freezers in which the packaged peas are held for one hour to six hours depending on heat transfer considerations. The contact-plate freezer is widely used because of flexibility, ease of expansion of freezer capacity, and because its pressure-plate mechanism results in more uniform packages, permits use of containers with thinner wall construction and lower cost, and permits use of containers of smaller size per unit of contents. In the plate freezers Freon, ammonia or brine is circulated in the hollow freezer plate between which the product is frozen. The refrigerant is maintained at a temperature of —20 to —30° F and the freezing cycle is about two hours for fruits and vegetables. The plates may be loaded manually or automatically and because contact between the refrigerated plates and packaged product is maintained under regulated pressure, the packages after freezing are flat and uniform in shape and the product expands to fill most of the space in the container. There is usually an additional loss of about 0.6% between grading and freezing, the final yield averaging about 82% of weight of vined peas.

Casing

After freezing, the cartons are cased in fiberboard cases that are closed, sealed and taped to reduce heat transfer by air movement.

Storage

The cased, frozen peas are stored at 0° F or below. Changes in color and flavor occur at storage temperatures above 0° F. Trained judging panels are consistently able to detect a color change in peas held at 0° F for 6 months, at 10° F for 2 months, at 20° F after 20 days and at 30° F after about 6 days. At 0° F steadily held, overall quality remains high for at least one year in properly blanched peas.

(For complete description of modern pea-freezing operation see P. Lamb and C. R. Harighorst. Top-rank quick-freeze operation. Food Eng. 25 (1): 68-73. 1953.)

field (Tressler and Evers, 96). While in the initial investigations major attention was given to quality attributes (such as color, flavor and texture), more recently attention has been diverted to adaptability to mechanical harvesting, resistance to insect pests and diseases and yield factors in the effort to increase productivity and decrease production costs.

The desirable characteristics of vegetables for freezing are still largely known by practical experience rather than by exact scientific knowledge. The present recommendations of these characteristics and typical varieties now being processed are given in Table 5.

The olericulturist is faced with the problem of developing selections and strains of varieties and production methods for obtaining maximum yields of produce of the desired quality under the most economical conditions. The processor is concerned with the determination of the maturity and degree of ripeness desired, of harvesting with least cost and least change in the desired qualities of the vegetable, of transport to the processing plant under conditions that produce the least changes in quality, and with determination of the characteristics that affect suitability of the vegetable to the various preparation operations and processes involved in preservation freezing. The selection of the particular variety planted, planting and culture, and its harvest and handling is based on previous variety trials on the assumption that varieties reproduce and behave much the

TABLE 5

DESIRABLE CHARACTERISTICS AND TYPICAL VARIETIES OF VEGETABLES FOR FREEZING

Vegetable	Desirable Characteristics	Varieties
Asparagus	Green, well colored, succulent stalks, medium size	Mary Washington, Martha Washington, U.C. Strains 499 and 500
Beans, lima	Green seed coat, green tender beans, easily opened pods	Large: Fordhook, Fordhook 242, Concentrated Fordhook Baby: Green seeded Henderson, Baby Potato
Beans, snap	Long, straight, stringless pods, bright green resistant to splitting or sloughing of skins	Pole: Stringless Blue Lake, Kentucky Wonder Bush: Tendergreen, Tenderlong, Giant Stringless, Landreth Stringless
Broccoli	Dark green color, tender stalks, compact heads	Early Green Sprouting, Italian Green Sprouting, Calabrese, Waltham
Brussels sprouts	Firm, compact, moderately large sprouts, deep green color	Half Dwarf Improved, Long Island Improved, Pacific Coast Half Dward
Carrots	Bright orange color, tender core and root, sweet flavor	Red Core Chantenay, Long Imperator, Dantes Half Long
Cauliflower	White curd, compact head, smooth surface, tender texture, medium stalks	Early Snowball, Snowball, Snowdrift, White Mountain
Corn	Brightly colored kernels, tender endoderm and pericarp (thickness of periderm is limiting factor), deep kernels, uniform maturity	Yellow: Tendergold, Golden Cross, Golden Freezer, Tendermost White: Evergreen, Silverliner, Narrow Grain, Moneymaker
Peas, green	Green seed coats and green cotyledons, tender, sweet, easily podded	Laxton, Laxton's Progress, Freezer, Perfection Freezer, Alderman
Spinach	Deep green color, succulent midrif, short stems, good flavor	Savoy, Viking, Nobel, Evergreen, Viroflay, Long Standing Bloomsdale

Source: D. K. Tressler and C. F. Evers. The Freezing Preservation of Foods, 3rd. ed., Vol. 1, pp. 364-397, 1957.
W. V. Cruess. Commercial Fruit and Vegetable Products, 4th ed. pp. 778-867, 1958.

same way from year to year. At present, quality is assessed to a large extent by visual characteristics such as size, shape, uniformity, color, freedom from blemish and flavor and texture. In the grade standards of the U.S.D.A., Agr. Marketing Service particular attention is given to absence of defects (degree of freedom from extraneous vegetable matter and blemished material that is discolored or spotted by pathological, insect, or mechanical injury), maturity and tenderness factors affecting texture after cooking, and color. Flavor and odor is also tested but is not rated numerically. The product after cooking is required to have a characteristic normal flavor and odor and to be free from any objectionable flavors and odors.

Visual external appearance is still used largely as a criterion of quality. Objective methods for appraisal of color and texture, however, have been introduced and are being widely used in controlling maturity for harvesting. Objective methods for flavor measurement have not been developed (A. D. Little, 64), although gas chromatography has been applied recently in the analyses of flavors. Ralls (1960) has proposed flash exchange gas chromatography for the rapid determination of volatile carbonyl compounds and organic acids in peas, and Buttery et al. (13) have applied gas-liquid chromatography to the analyses of potato granules to determine the rate and extent of off-flavor changes as a result of oxidative rancidity of the lipides present. Taste difference testing (Boggs and Hanson, 9) is still the basic means of flavor appraisal. The fact that flavor appraisal by taste panels remains reasonably constant even over long periods was reported for frozen cauliflower and spinach by Boggs et al (8). The chemical constituents that determine flavor, the genetic factors that control their biosynthesis and accumulation, and the nature of the agencies involved in changes in these constituents are still largely unknown so that geneticists and plant breeders still have to depend largely on empirical observations for selection of varieties. While color can be measured objectively and while the metabolic pathways for the synthesis of some of the plant pigments are known, complete genetic control over color is not possible and neither is the genetic control over texture.

Extensive changes in structure, physiological activity and chemical composition are known to occur during ripening. While many of the chemical changes that occur have been studied, the nature of ripening is still unknown. Though ripening cannot be explained completely, its rate can be influenced by control of environmental conditions such as temperature. Post-harvest physiological changes are known to occur in vegetables after harvesting and they may often be exceedingly r[illegible]nd intensive. While our knowle[illegible]ot post-harvest physiological changes in fruit is more detailed, there is considerable information on post-harvest physiological changes in vegetables (Pentzer and Heinze, 76). These changes are controlled largely by rapid precooling and maintenance of low temperatures during hauling and holding prior to pressing (Wright et al., 103; Guillou, 26). Cooling after harvest may be accomplished by air cooling, hydro cooling, vacuum cooling or ice cooling, but in the application of these methods it is necessary to avoid undesirable effects. Until recently it was believed that cooling should be as rapid as possible in order to quickly reduce the temperature of the tissue close to 32°F to reduce respiration and chemical change. There is some evidence now that for apples at least too rapid a cooling may be undesirable. Certain plums exported from South Africa have longer storage life if stored for two weeks at 31°F and then at 45 or 50°F; brief exposure to high temperatures during the storage period has been shown to give longer storage life at 31°F (Tomkins, 94). It is known that precooling potatoes

to too low a temperature results in undesirable sweetening by conversion of starch into sugars. The effects of low temperature on biological systems, particularly fruit tissue, have been discussed by Fidler (22).

The storage life of certain fruits is considerably prolonged if they are stored not in air but in an atmosphere in which the oxygen concentration is reduced and the concentration of carbon dioxide increased. The conditions of temperature and concentrations of oxygen and carbon dioxide suitable for a number of varieties of fruits have been determined and these are widely used in controlled atmosphere or gas-storage. The optimum rates of change of temperature and concentration of carbon dioxide and oxygen during the initial period, however, remain to be determined. Whether changes in all three factors during storage to obtain maximum storage life are necessary or not also remains to be investigated.

With vegetables, particularly those that respire rapidly and are physiologically active, depletion of oxygen from the surrounding environment during cooling is undesirable because it leads to sub-oxidative tissue metabolism resulting in formation of undesirable flavors and physiological damage. Vegetables precooled in cold water or with ice should not be held submerged in or covered by water too long. While some data are available on the effect of temperature in rate and extent of chemical change in vegetables there is little information on the effect of changes in concentration of oxygen and carbon dioxide in the environment on quality.

Data on chemical composition of vegetables until recently was limited largely to gross proximate composition in terms of ash, crude fiber, carbohydrates, proteins, and lipides. As a result of the introduction of newer methods of analyses, particularly those of partition chromatography and spectroscopy, more detailed information on a number of naturally occurring plant constituents was obtained, but this is still limited. The unequal distribution of many constituents in vegetable tissue, as a result of established physiological gradients and the factors influencing the distribution are still but incompletely known. The gross chemical composition may be the same but there may be differences in color, flavor, and texture. Differences in the same variety from season to season and locality to locality are known to occur and the chemical composition and physiological activity of individual vegetables (stalk, stem, leaf, root, or fruit) may occur. It is known that cultural conditions, particularly fertilizer, will affect composition, keeping quality and processing quality. Thus the tendency of potatoes to undergo non-enzymic stem and blackening has been correlated with potash and other mineral deficiencies, with certain soil type, and with cool weather during maturation. This type of blackening is due to a combination of iron with chlorogenic acid and is influenced by the presence and accumulation of citric acid which chelates iron and makes it unavailable for reaction with the colorless precursor of blackening.

The processor is limited to use vegetables which are free of insects and insect parts, insect damage or uncontaminated by insect excreta. On the other hand, he is limited also by the requirement that the frozen vegetables be free from residues of agricultural chemicals. Shortly after the end of World War II, a wide variety of organic insecticides, fungicides and herbicides were introduced and used. Herbicides ranging from kerosene emulsions to plant growth regulators were used to control weed growth, but although more economical and more efficient than hand or mechanical weed control, introduced the problem of formation of off-flavors if improperly applied or the possibility of contributing to health hazards by being absorbed and present in the tissues. Similar problems were en-

countered with pesticides that efficiently controlled plant disease and insect infestation but introduced residue problems. Because of the economies resulting from their use, more reliance was placed on these pesticides than on development of varieties resistant to plant pests and diseases. Shortly after their initial widespread use, it was established that certain of these agricultural chemicals resulted in undesirable changes in flavor not only in produce as harvested but after processing by canning or freezing. In recent years the U.S.D.A. sponsored regional projects to determine the effect of pesticides and herbicides used singly and in combination on the flavor of processed fruits and vegetables. The results of the six year project in the northeast region have been published (Murphy et al., 73; McArdle et al., 67).

The data reported indicate that five of the single insecticides and one of the single fungicides were associated with a notable degree of poor flavor quality. Six combinations of insecticides had adverse affects on flavor. Some of these appeared to be related to specific components of the multiple treatments while others were ascribed to interactions. With herbicides, off-flavors were not as marked but 6 slight off-flavor tests were observed, 2 of them with sweet corn.

Enzymatic Changes and their Control. The preservation of vegetables and their products by freezing depends on the retardation in rate or inhibition of the post-harvest physiological changes, both enzymatic and nonenzymatic, and in the control of microbial deterioration by decrease in storage temperature. To preserve vegetable products for the relatively long storage period commercially desired, however, storage at temperatures well below those at which ice formation occurs is required. Commercial preservation by freezing requires freezing to, and storage below, 0°F. Preservation is accomplished by the combination of ice formation and low temperature. Freezing and freezing storage alone is not sufficient to prevent changes in flavor, texture, color, and nutritive value because of enzyme activity. It is now well established that unblanched or underblanched vegetables undergo changes in flavor due to abnormal enzyme activity, changes in color due to decomposition of chlorophyll, carotenoid, and flavonoid pigments, and loss in vitamin content (carotene, thiamine, riboflavine, and ascorbic acid). The available data on enzyme activity in frozen vegetable tissue responsible for changes in color and flavor during freezing storage was summarized by Joslyn (38, 39) and Joslyn and Diehl (47). Joslyn (39) called attention to the fact that enzyme activity in frozen vegetable tissue was similar to that which occurred in concentrated solutions or in dried tissue.

Shortly after Kohman and Sanborn (54) showed that vegetables stored under conditions of low oxygen tension or subjected to mechanical bruising underwent abnormal respiration leading to the accumulation of acetaldehyde and alcohol, Joslyn and his associates, during the period of 1935-1940 (Joslyn, 38), reported that aldehyde accumulates in raw or underscaled artichoke hearts, asparagus, brussels sprouts, green snap beans, peas, lima beans, and squash progressively during freezing storage. The rate and extent of accumulation of acetaldehyde was reduced as the temperature and time of blanching increased and did not occur in tissue blanched sufficiently to completely inactivate peroxidase. In broccoli and spinach ethanol and not aldehyde accumulated. In both broccoli (Joslyn and Buck, 43, 44) and in peas (Joslyn and David, 46) acetoin and other volatile carbonyl compounds were found to accumulate. Although acetaldehyde does not contribute directly to the off-flavor, its production was related to off-flavor formation. Ralls (80) recently reported that volatile carbonyl compounds obtained by flash exchange gas chroma-

tography do not have the characteristic pleasant odor of cooked peas. On the other hand, Gutterman et al., (27) clearly demonstrated that whenever the acetaldehyde level in frozen peas and asparagus exceeded a certain range, organoleptic taste panels have invariably classed the product as being of inferior quality or inedible.

The odor and flavor developed during freezing storage of unblanched frozen vegetables resembles somewhat that developed in unblanched or underblanched dehydrated vegetables or fresh vegetables held at low oxygen tension at room temperature. Color changes as a result of destruction of chlorophyll and carotenoid pigments are similar in frozen and dehydrated vegetable tissue. Each vegetable, however, appears to develop a characteristic odor as indicated below:

Artichoke hearts—Sharp silage odor with distinct fishy overtones
Asparagus—Sharp silage odor resembling composted grass
Beans, green—Sweet cut alfalfa odor
Beans, horse—Pungent sweet butyric odor
Beans, lima—Oil of bitter almonds odor at first and subsequently strong oxidized linseed oil odor
Brussels sprouts—Stale cabbage odor
Peas—Fruity alfalfa odor
Spinach—Sharp odor of composted grass
Squash—Sharp acrid odor

The presence of several volatile carbonyl compounds and particularly the accumulation of acetoin and biacetyl in peas and broccoli was related to activity of pyruvic carboxylase. Ralls (79), however, reported the presence of appreciable concentration of acetoin in asparagus, beets, peas and spinach and found that the acetoin level of blanched frozen peas increased on heating. Canned vegetables were found to contain considerably more acetoin and biacetyl than fresh or frozen ones. The increase in acetoin during heating of frozen blanched peas and the presence of acetoin in canned vegetables was ascribed by Ralls to the thiamine catalyzed conversion of pyruvic acid which was first demonstrated by S. Mizuhara in 1951 who first showed acetoin production at pH 8.4 from pyruvic acid, acetaldehyde, and thiamine. Acetoin formation by this reaction is affected by pH and thiamine level. Whether formation of acetoin by this means during blanching accounts for the quantities found in frozen vegetables or not is not known.

The formation of pyrrolidone carboxylic acid from glutamine was reported by Rice and Pederson (83) and Shallenberger and Moyer (85) to be related to formation of bitter medicinal or phenolic off-flavors formed in beet purees during heat treatment and subsequent storage. More recently Mahdi et al., (68) found pyrrolidone carboxylic acid in 22 processed fruits and vegetables in concentrations varying from 0.008% in commercially canned sweet corn to 0.26% in beets. Mahdi et al., (68) found that addition of this acid causes a detectable off-flavor when its concentration exceeds 0.05% in sweet corn, 0.10% in green beans or peas, and 0.15% in beets. In vegetables other than beets the PCA level likely to be present is too small to contribute significantly to off-flavor. It is unlikely that glutamine decomposition can be a factor in off-flavor development in frozen vegetables because these are not normally heated to temperatures high enough or for periods long enough to result in appreciable glutamine decomposition.

The most likely cause of off-flavor formation in underscaled or unscaled frozen vegetables is the enzyme-catalyzed oxidative deterioration of lipides. The lipide content of vegetables is small, vary-

ing from 0.1-0.2% in leafy vegetables (as crude lipide fresh weight basis), 0.2% in asparagus, 0.3% in green beans and cabbage, 0.4% in carrots and brussels sprouts, 0.5% in peas, 0.8% in green lima beans to over 1.0% in sweet corn. The crude lipide content on a dry weight basis, however, amounts to 1.25 to 3.33% by weight of the vegetable tissue solids. Lee and Wagenknecht (see Lee, 57) have reported data during the period of 1951 to date indicating that the development of off-flavor in frozen vegetables, particularly peas and sweet corn, is accompanied by increase in free fatty acid content, decrease in iodine value, and increase in peroxide value. Their contention that lipide oxidation is a major factor in off-flavor development is strengthened by the fact that the gradual development of oxidation off-flavors in dehydrated potato granules was due to autoxidation of the small amount of crude lipides (about 0.3% of the dry weight) present in potato tissue. Buttery et al., (13) reported the presence of linoleic and linolenic acids in potato lipides and found the oxidative degradation of linoleic and linolenic acids to be fairly closely correlated with actual volume of oxygen absorbed and with the degree of off-flavor of the reconstituted product. Linoleic acid was found to constitute 53.3% and linolenic 22.6% of the fatty acids present in commercial granules.

The lipides of vegetables other than potatoes have not been investigated until recently. Lee and Mattic (61) fractionated the crude chloroform—methyl alcohol extract of lyophilized peas (which amounted to about 1.2% in comparison with crude ether extract of 0.4% on fresh pea tissue basis) into phospholipide, neutral fat and free fatty acid components. Of the total fatty acids determined in untreated frozen peas, their data indicated the presence of 39.8% linoleic acid, 6.0% oleic acid, 1.2% linolenic acid; the rest being chiefly palmitic acid with traces of capric, myristic, and stearic acid. Lee (56) had previously reported that the iodine number of ether extracted lipides of frozen vegetables ranged from about 99 for snap bean and pea to about 120 for asparagus and lima beans. These values compare with 100-120 for corn oil which is known as a rich source of linoleic and linolenic acids.

In their original investigation Lee and Wagenknecht (62) had reported a marked increase in acid number of crude lipides of unblanched frozen vegetables particularly in asparagus, snap beans, peas, spinach, and sweet corn), with smaller increases in peroxide value (sweet corn, peas, spinach, and snap beans) and possible but erratic changes in iodine number in comparison with blanched vegetables. Subsequently they reported progressive increase in acid number and peroxide number in unblanched frozen peas, snap beans, and sweet corn but no increase in blanched vegetables. They attributed the increase in free fatty acids to the activity of lipase and oxidation of unsaturated acids to lipoxidase activity. The addition of soybean lipoxidase to blanched vegetables, however, did not result in increase in off-flavor during freezing storage (Lee and Mattick, 1961). In confirmation of previously published data they found marked increases in free fatty acids of the lipides of peas in unblanched peas stored for 1 year at 0°F in comparison with enzyme-inactivated peas. The phospholipide and neutral fat content decreased during storage of raw peas in comparison with enzyme-inactivated peas while the free fatty acid content increased. A larger amount of the free fatty acids came from the phospholipide fraction and smaller amounts from neutral fats. An appreciable increase in the palmitic acid content of the neutral fat fraction was observed and was attributed to oxidation of the C_{18} unsaturated fatty acids in this fraction. The major enzymatic change in pea lipides, however, was caused by lipase activity.

Lipase activity alone would not ac-

count for the characteristic off-flavors developed during freezing storage. The presence of lipoxidase in peas and sweet corn was demonstrated by Wagenknecht and Lee (99), Wagenknecht (98), and Siddiqui and Tappel (87). The presence of linoleic and linolenic acids has also been demonstrated in peas by Lee and Mattick (61). The lipoxidase catalyzed oxidation of linoleic acid is characterized, however, by relatively higher activity at temperatures near freezing than is true for other enzyme systems but a more marked reduction on freezing (Tappel et al., 93). It is well known that enzyme activity is reduced by change of state as a result of freezing and ice separation and that enzyme activity in the frozen state is considerably lower than in the undercooled state at the same temperature.

There is yet insufficient evidence that changes in flavor during freezing storage are related to lipoxidase activity and that the rate and extent of off-flavor parallels the oxidative changes in unsaturated fatty acids. During the auto-oxidation of unsaturated fatty acids there usually is an accumulation of malonyl aldehyde. Oxidative rancidity in many food products can be detected by the formation of the characteristic pigment from reaction of malonyl aldehyde with thiobarbiteric acid. While the specificity of this test has recently been disproven (Patton, 75; Neukom, 74), it has been useful in detecting fat oxidation in many products since it is quite sensitive. It should be applicable to detection of changes in the lipides of frozen vegetables but as yet has not been applied.

Progressive changes in color during storage of unblanched frozen vegetables have long been known to accompany changes in flavor. The color change is partly due to conversion of chlorophyll into the brown pheophytins. Quantitative data on chlorophyll degradation was published first by Mackinney and Weast (66) for frozen peas and snap beans. Destruction of carotenoid pigments by oxidation is also known to occur. Lee (56) and Wagenknecht et al. (100) reported data on changes in carotene and chlorophyll content during freezing storage. They attributed losses in carotene content to induced oxidation of carotene by lipoxidase and changes in chlorophyll content to chlorophyllase activity and peroxide oxidation. Chlorophyllase, however, is known to occur in leafy vegetables but not peas, beans, or asparagus and the chlorophyllins formed by its action are known to be more heat stable than chlorophyll itself. The breakdown of chlorophyll by chlorophyllase was investigated recently in some detail by Holden (32). Chlorophyll degradation and carotene loss occurs also in blanched vegetables stored at temperatures above 0°F. In recent investigations on time-temperature tolerance of commercially frozen foods, chlorophyll conversion to pheophytin was measured in snap beans and spinach (Dietrich et al., 19) and peas (Boggs et al., 10).

Carotene retention data were also obtained for spinach. The conversion of chlorophyll to pheophytin was found to be closely correlated with reflectance color measurement and subjective evaluation of color by test panels. Chlorophyll conversion to pheophytin occurred at appreciable rates at storage temperatures above 0°F and the rate of conversion increased with increase in temperature. Chlorophyll retention was highest in spinach, next in peas, and least in green beans. The storage time at which first changes in color were observed at 0°F were 350 days for spinach, 202 days for peas, and 101 days for snap beans. For comparison, at 10°F the respective storage times were 70, 48, and 28 days.

Blanching to prevent undesirable changes in color and flavor during freezing storage is still carried out empirically. The typical blanching conditions used industrially in freezing vegetables are shown in Table 6 in comparison with

TABLE 6

BLANCHING CONDITIONS FOR CANNING AND FREEZING

Vegetable	Preparation for Canning	Preparation for Freezing
Asparagus	1½-3 min. in steam at 210°F	2-3 min. in steam at 210°F
Beans, lima	2-3 min. in hot water at 190-200°F	2-3 min. in water or steam at 210°F
Beans, green	1½ min. in hot water at 185-190°F	2-3 min. in water or steam at 190°F
Broccoli	3 min. boiling dilute brine	3-3½ min. in steam
Brussels sprouts	4 min. in hot water at 210°F	3-4 min. in steam
Carrots	2-4 min. in water at 190°F	2-3 min. in water at 210°F
Cauliflower		3-4 min. in steam at 210°F
Corn	Corn on cob not blanched, cut corn blanched before cutting	Corn on cob 6-11 min. in steam; cut corn, steam cobs 2-3 min. before cutting or cut corn 3 min. after cutting
Peas	1½-5 min. in water at 190-200°F	1-2 min. in water at 190°F or 1-3 min. in steam at 210°F
Spinach	2-3 min. at 212°F or 6 min. at 170°F	2-3 min. in steam at 210°F

Sources: Anon. A Complete Course in Canning. 8th ed. 377p. The Canning Trade, Baltimore, Md., 1958. See p. 84-181.

Cruess, W. V. Commercial Fruit and Vegetable Products. 4th ed. 884 p. McGraw-Hill Book Co., New York. 1958. See p. 221-300, 778-867.

Tressler, D. K., and Evers, C. F. The Freezing Preservation of Foods. 3rd ed., Vol. I. Freezing of Fresh Foods, 1214 p. Avi Publishing Co., Westport, Conn. 1957. See p. 398-465.

those used in canning. In canning, blanching is used to: expel intercellular gases, wilt or shrink the tissue, prevent internal pressure strains during heat processing, develop higher vacuum in the closed container, obtain proper fill, inhibit enzymatic changes during preparation for processing, better retain quality and nutritive value, facilitate peeling, cutting, dicing or other preparation, remove raw flavor such as viner taste in peas and beans, bitterness in asparagus, etc., and to set the color. In freezing, blanching serves primarily to inactivate enzymes responsible for changes in color, flavor, and nutritive value, and to facilitate packing of leafy vegetables and stem vegetable tissue.

Considerable changes occur in chemical composition and cellular structure of vegetable tissue during blanching. Weir and Stocking (102) summarized the available information concerning histochemical changes in cellular adhesion due to modifications in pectic substances, changes in starch granules occurring in root vegetables as a result of gelatinization by heat, changes in chloroplasts and chromoplasts in which the carotenoid pigments and chlorophylls change in state and are dispersed or dissolved in the lipides present, and changes in intercellular air spaces. During blanching the intercellular air is displaced and the air spaces are filled with liquid. Chemical changes during blanching are discussed by Lee (57).

In the canning operations, advantage is taken of the enzymatic activity of chlorophyllase since chlorophyllins are more heat stable than native chlorophylls. Chlorophyllase activity is promoted in spinach by blanching at low temperatures for longer time rather than at higher temperature for a shorter time. In freezing, however, high-temperature short-duration blanching results in better chlorophyll retention than relatively low-temperature long blanching, at least for green snap beans, (Dietrich et al., 18). This apparently is related to changes in pectic constituents. Hoogzand and Doesburg, (33) took advantage of the naturally occurring pectin esterase of cauliflower to improve texture by blanching at 158°F for 15 minutes in presence of calcium chloride in preference to shorter blanch at higher temperatures.

A considerable loss in water-soluble constituents occurs during blanching with consequent loss in sweetness and nutritive value. This loss is more serious in later stages of blanching when the tissue cells have been killed and leakage of cell sap from the killed cells occurs and particularly the chilling following blanching (Hohl et al., 31). The extent of the changes in composition that occurs as a result of leaching during blanching is summarized by Lee (57). In order to reduce these losses serial blanching in water, steam blanching and radio frequency heating have been investigated. Radio-frequency blanching and ionizinz radiations resulted in smaller losses in soluble nutrients (Proctor and Goldblith, 78). At present unsolved technological and economic factors limit the application of these processes. Industrially, best results are obtained by steam blanching followed by chilling with the minimum contact with water. The use of nonaqueous blanching media has as yet not been investigated although these are technologically promising. The superior color and flavor of vegetables prepared by the Chinese method of cooking in hot oil or fat is widely known. It is possible to adapt this process by taking advantage of the blanket of steam which forms about the surface of vegetables quickly immersed in hot oil which protects them against oil absorption. Synthetic water-repellant liquids of high heat capacity, such as the silicones, are available and might be applied to blanching.

Platt et al. (76a) have called attention to the rapid inactivation of enzymes by immersion in hot oil in the Chinese method of cooking and have proposed a method of drying by heating in edible oils in vacuo. By avoiding preliminary steam or hot water blanching the consequent loss or destruction of water soluble constituents is prevented.

In the control of the blanching process, early observations indicated that catalase or peroxidase activity could be used as indices of heat inactivation because their rate of destruction paralleled that of the unknown enzymes actually involved in off-flavor formation (Joslyn, 38). Joslyn (37) proposed that peroxidase activity rather than catalase activity more closely parallels off-flavor production. Peroxidase activity has been used as an index of the extent of heat inactivation in brussels sprouts, peas, snap beans, and spinach in recent investigations but has not been adopted industrially because of lack of a satisfactory and reproducible assay. The applicability and reproducibility of several peroxidase assay methods was investigated by Joslyn (40) and an ascorbic acid oxidation assay proposed as being most promising. A test paper impregnated with urea peroxide and o-tolidine was proposed recently by Morris (71) for rapid testing. Both methods are now being subjected to collaborative testing to determine their precision and reproducibility. The regeneration of peroxidase activity at room temperature following partial inactivation has been observed, but this is known not to occur during freezing storage.

The Rate of Freezing. The preservation by freezing is effected by a combination of low temperatures and ice formation. The formation of ice in frozen tissues results in undesirable changes in texture because of concentration of solutes, dehydration of tissue constituents, and mechanical factors. Under normal conditions, plant tissues lose crispness on freezing, and preservation by freezing is applicable only to those vegetables which are cooked in preparation for use because the inevasible, structural changes produced by freezing are similar to those produced by heating. The preservation by freezing of salad vegetables (lettuce, cucumber, radishes, etc.) is not feasible by the commercial methods now in use. The water which separates out as ice in plant tissues frozen to temperatures of 0°F or below is only partly reabsorbed after thawing. It is due to the irreversi-

bility of this process that changes occur in chemical composition and structure of vegetable products during freezing, storage, and subsequent thawing. These changes are known to be influenced by the morphology and histochemistry of the plant tissue selected, by preparation for and method of freezing, by freezing storage conditions, and by thawing conditions. The histological and histochemical changes occurring during the freezing and thawing of animal tissues and products have been intensively investigated and considerable progress has been made in developing ideal conditions for the preservation freezing of meat, fish and poultry products. The earlier histological developments in this field were reviewed by Glennie (24) and more recent investigations are summarized by Tressler and Evers (96). Our knowledge of the effect of freezing on histological and histochemical changes induced in vegetables is less complete (Weir and Stocking, 102; Joslyn and Diehl, 47).

In the last twenty years considerable progress was made toward the understanding of the nature of changes involved in freezing injury of cellular materials, particularly animal tissues, and successful methods have been developed of avoiding this injury and permitting the survival of living cells.

It has been demonstrated that the cryotolerance of enzymes, viruses, bacteria, cells, or even tissues could be increased by the inclusion of protective substances in the suspending medium. Glycerin has been widely used to minimize destruction of sperm suspensions and prevent loss of biological activity of both soluble enzyme and particulate enzyme preparations (Harris, 28). More recently, dimethylsulfoxide has been introduced for this purpose (Ashwood-Smith, 3; Greiff and Myers, 25).

The present knowledge of the basic mechanisms involved in freezing and in drying is summarized in the proceedings of a recently held conference (Meryman, 69). Meryman considers the freezing of biological materials to involve primarily physical phenomena. During the lowering of the temperature of a tissue or cell suspension there is first a metabolic imbalance created by low temperatures above freezing; this is reversible if not too extensive. In living plant tissues, however, this metabolic imbalance often leads to progressive and irreversible physiological damage (Fidler, 22). The second dominant phenomenon associated with a lowering of temperature is the change of aqueous phase occurring during ice formation. The first step in the development of ice crystals is the formation of homogeneous or heterogeneous crystal nuclei of critical size. Nucleation may, however, be suppressed by supercooling, and it is possible to lower the temperature of a tissue without ice crystallization.

Once a crystal nucleus has developed, crystal growth and ice formation occur. At ordinary rates of freezing in animal and plant tissues, ice formation occurs only outside the cells. Water is withdrawn from both within and without the cell and ice crystals form and grow in the extracellular spaces. The withdrawal of water from the tissues results in a concentration of the solutes present in these tissues. Not all the water present will freeze out. The "free" water present as a solvent for crystalloids and dispersions medium for celloids will separate out first, followed by crystallization of loosely bound water several degrees below the initial temperature of ice formation. The tightly bound water, which constitutes 8-10% of the water content of mammalian tissue, never freezes. In this respect freezing is similar to dehydration, for the bound water in foods also can not be removed completely in drying (Kuprianoff, 55). In aqueous solutions and biological materials several phase transitions occur during ice formation. Dowell and Rinfret (21) have recently called attention to the existence of several low temperature forms of ice demonstrable by

differences in X-ray diffraction. Luyet and his collaborators (see Meryman, 69) have reported various phase transitions occurring in aqueous solutions and tissue at low temperature. Depending primarily on the cooling velocity, these include solidification in the amorphous state, transformations within the amorphous state, various forms of incomplete crystallization, various types of recrystallization, and passage from one crystalline system to another. The temperature dependence of ice crystal nucleation and growth rate were investigated in some detail by Stephenson and others (see Meryman, 69).

The similarity between freezing and dehydration is further evident in recent investigations of photochemical reactions in frozen solutions. Szent-Györgyi (89, 90) observed differences between photochemical reactions in liquid aqueous solutions and in frozen aqueous solutions and suggested that, in the latter case, formation of crystalline ice forces the solute molecules into solid aggregates. He found that the phosphorescence observed in frozen solution also occurs in a dry film. Similarly, Wang (101) found photodimerization of pyrimidines to occur on inactivation of frozen solutions or as a dry solid film. Shimazu and Sterling (86) observed an increase in crystallinity of cellulose and calcium pectinate during dehydration, rapid dehydration resulting in somewhat greater crystallinity than slow dehydration. The effect of freezing on the macromolecular structure of natural high polymers such as cellulose, starch, pectin, and related hemicelluloses involved in textural quality of food products has not been investigated as yet.

In the earlier investigations considerable emphasis was placed on the effect of rate of freezing on the size and distribution of the ice crystals formed. Although it is now known that this can be controlled by the rate of heat removal during the period of maximum ice formation, low temperature gradients were used largely to achieve rapid freezing and the so-called "quick freezing" technique based on refrigerant temperatures of —20°F or —40°F were emphasized. The dependence of the cooling rate on other heat transfer determinants (size, shape, and thermal properties of the food being frozen; physical and thermal properties of the refrigerant; and the velocity of flow of refrigerant relative to the product) were largely neglected. The release of latent heat of crystallization during growth of ice crystals and its consequent modification of the course of cooling also was not recognized (Stephenson [see Meryman, 69]).

In general, when foods are frozen slowly the ice crystals are large and are distributed non-uniformly. In meat products, large ice crystals form between the meat fibers and may cause rupture and dislocation of the fibers. In plant tissues, ice gradually fills the intercellular space and eventually forces the cells apart but may or may not cause rupture of the cells. When animal or plant tissues are frozen so rapidly that translocation of water does not occur before freezing, many small uniformly distributed ice crystals are formed. Such tissues were earlier believed to be much less disorganized and superior in texture after thawing than were slowly frozen tissues. It has long been known to biologists, however, that intracellular freezing results in more disorganization than extracellular freezing and is nearly always fatal to living tissues. Joslyn and Marsh (50) compared the effects of freezing rapidly in solid carbon dioxide at —110°F with those in still air at 0°F on the texture of several fruits and vegetables and observed that only with asparagus was the texture on thawing improved. Lee et al. (58, 59) re-investigated the effect of rate of freezing on texture. With green beans and peas they found that, although the ice crystals formed on slow freezing were larger than those formed in rapidly frozen vegetables, they could

not demonstrate detectable differences in flavor, texture, or nutritive value after cooking. Differences in leakage loss during thawing and texture changes in asparagus were observed (Lee and Johannessen, 60).

The fact that rapid freezing may not result in improvement in texture retention does not detract from the importance of rapid cooling of vegetables for optimum preservation. During the cooling, freezing, and freezing-storage of vegetables three separate phases of heat transfer and temperature change have long been recognized (Joslyn and Marsh, 50). During the first or chilling phase, the temperature of the product is reduced from ambient to the initial freezing point, i.e., the initial phase of ice formation. The average temperature of the product should be lowered at this stage from room temperature to the freezing temperature sufficiently rapidly to prevent microbial activity. The rate of chilling required will be determined by the extent and type of infection and the composition of the food product. Delayed chilling and slow cooling may result in serious changes in appearance and flavor. The biological "zero" for growth varies with the composition of the product, packaging conditions, and type of organism. It was considered to be 32°F but is now believed to be somewhere between 15 and 20°F.

In the second phase, ice formation is initiated and continues until most of the water is present as ice. In this phase of maximum ice formation, the temperature drops only slowly and remains fairly constant because of the liberation of the latent heat of crystallization. The initial temperature at which ice formation first occurs and the temperature range during the phase of maximum ice formation varies with the composition of the food, particularly its total water content and the proportion of the water present that can be separated as ice by freezing. The shorter the time required to pass through this phase, the more uniform is the ice formation. It does not necessarily follow that this is the only factor influencing texture. In asparagus, chilling to the second phase and holding at the phase of maximum ice formation until nucleation and initial ice formation has occurred results in as good texture retention as completing the entire freezing cycle under these conditions (Joslyn and Kilner, 49).

In the third and final phase, the temperature of the product decreases to the desired storage temperature of 0°F or below. It represents essentially the cooling of the frozen product. Although additional ice formation occurs in this range, it is to a much smaller extent than in the phase of maximum ice formation. The rate of cooling is generally slower than in the chilling stage not only because of decreased heat conductivity and heat capacity, but also because of a lower temperature gradient.

Economic as well as technological considerations are involved in selection of optimum conditions of freezing. Prompt chilling and rapid freezing are established practices as much because of economic factors as technologial. Overall refrigeration and freezer equipment costs are less if freezing is accomplished quickly and the temperature of the product is lowered to the desired storage temperature. Liquid immersion freezers have been found to be more economical where applicable than are contact plate freezers or air-blast freezers. Their use is limited to products packed in hermetically sealed, liquid-tight containers such as cans since the liquid refrigerant used may contaminate the product. Freezing in sirups was proposed early for fruit but was not practical. During the war, the Germans proposed and experimented with freezing in liquid nitrous oxide at —129°F (Mackinney, 65). More recently, freezing in liquid nitrogen at —320°F was proposed (1) not only for improving texture retention but also for improved preparation and recovery of corn kernels from corn on the cob. It is claimed that tomatoes

frozen in liquid nitrogen retained their succulence. While previously the costs of freezing in liquefied gases was high, today costs of about 1¢ per pound greater than conventional methods are believed possible. This type of ultra-quick freezing is still in the development field but may be of great industrial importance.

Freezing Storage and Distribution. The quality of even properly prepared, blanched and frozen vegetables may deteriorate if they are not stored at a sufficiently low temperature during commercial warehouse storage and if they are not protected against damage during shipment to distribution centers and in retail storage. Until very recently there was only limited data on the storage deterioration and time-temperature tolerance of frozen foods. The meager data available on storage and transport conditions as they affect quality was summarized by Joslyn and Hohl (48), Joslyn and Diehl (47), and by Tressler and Evers (96). As part of the extensive program of investigation on the temperature-time tolerance of frozen foods undertaken in 1948 by the Western Regional Research Laboratory of the U.S.D.A. at the request of the industry, detailed data were obtained with three vegetables: frozen green snap beans (because they are among the least stable of popular frozen vegetables under commercial conditions of handling) were selected as a pod type vegetable, peas as a seed type, and spinach as a leaf type. In order to determine changes in quality occurring during transport, storage, and wholesale and retail selling, data were obtained on temperature fluctuations at all points of the commercial storage and distribution chain and also data on rate and extent of changes in quality at various storage temperatures.

Data on 19 lots of green beans obtained from 12 different packers during 5 harvest years (1952 through 1956) from 6 important producing areas were reported by Dietrich et al. (20). Fourteen lots of green peas obtained during 6 harvest years (1952-1957) were investigated by Boggs et al. (10) and 6 lots of spinach from 2 districts were studied by Dietrich et al. (20). Both objective and subjective evaluation of quality were used in determining changes during storage at various temperatures, singly and in combination. The quality of green snap beans was measured by determination of changes in reduced ascorbic acid content, conversion of chlorophyll to pheophytin, reflectance color, and subjective evaluation of color of thawed uncooked green beans and flavor of the cooked vegetable. Similar tests were made on peas and spinach and in data on carotene retention as well as chlorophyll retention was also reported for spinach. In general the data obtained indicated that changes in color occurred earlier and were more easily detected than changes in flavor. Green beans were more sensitive to changes in flavor and color and peas were more stable. Quality loss occurred faster as the temperature was increased. The extent of change is determined both by temperature and time, but temperature damage once it occurred was retained indefinitely and not corrected by return to zero and lower temperature. For frozen vegetables the following time and temperature were approximately equivalent:

1 year at 0°F
6 months at 5°F
3 months at 10°F
3 weeks at 20°F
10 days at 25°F
5 days at 30°F

Temperature damaged green snap beans first darken in color, later turn olive drab and eventually brown. Peas turn grayish-green and then yellowish. Spinach changes from vivid green to very yellow or grayed green. The first detectable difference in color in green beans occurred after 101 days at 0°F, 28 days at 10°F, 15 days at 15°F, 8 days at

20°F and 4 days at 25°F. With peas color first changed after 202 days at 0°F, 98 days at 5°F, 48 days at 10°F, 23 days at 15°F, 11 days at 20°F, and 5 days at 25°F. Spinach was intermediate.

The first detectable changes in flavor occurred in green beans after 296 days at 0°F, 94 days at 10°F, 53 days at 15°F, 30 days at 20°F and 17days at 25°F. With peas flavor changed after 305 days at 0°F, 166 days at 5°F, 49 days at 10°F, 27 days at 15°F, and 14 days at 20°F. Spinach changed in flavor after 700 days at —10°F, 200 days at 0°F, 110 days at 5°F, 50 days at 10°F, and 25 days at 20°F. Little or no change occurred in vegetables stored at —20°F or below.

The remarkably high sensitivity to storage deterioration as temperature increases above O°F indicates the desirability of holding frozen vegetables at 0°F or below. While deterioration gradually occurs even at 0°F, properly packaged frozen vegetables will retain high quality for many months. Under normal conditions of turnover of commercial stocks frozen foods held continuously at 0°F or below will reach the consumer in excellent conditions. Exposures to a higher temperature for brief periods, a few days at 10°F or a few hours at 20°F will not cause appreciable harm.

Frozen Vegetable Products. Frozen vegetables are available either as single trimmed, whole, cut, diced, or chopped. Green beans are marketed as regular or french cut; corn as cut corn or corn-on-cob; carrots diced; asparagus as spears, tips or cuts. Mixed vegetables, peas and carrots, lima beans and corn, and other mixtures and chopped or pureed spinach, broccoli and other vegetables are marketed. With the exception of potato products and certain Chinese vegetables, vegetables usually are marketed in blanched but not precooked condition. Potato products are prepared or precooked as frozen french fries, as potato patties, as baked potatoes, etc., and interest is growing in other precooked vegetable specialty products (Tressler and Evers, 96).

The possibility of combining dehydration and freezing for the preparation of newer products has occurred to several. Joslyn (35), proposed partial dehydration before freezing to minimize undesirable changes in texture on freezing. Havighorst (29) proposed combination of dehydration and freezing for postwar utilization of existing but then unused dehydration facilities. This process, however, was developed at the Western Regional Research Laboratory by a combination of dehydration to 50% moisture content and subsequent freezing. Although the process termed "dehydrofreezing" was developed in 1945, retail outlets have developed slowly but the process has found favor in institutional trade and for remanufacture. In this process the prepared fruits or vegetables are subjected to an initial rapid dehydration in which the moisture content is reduced from 90% to 50% with minimum change in flavor and significant decrease in weight and volume. The partially dried product is then packaged and frozen with considerable economy over conventionally frozen product (Talburt and Lindquist, 91); Talburt [in Tressler and Evers, 96]).

The preserving of pureed vegetables for infant and child feeding by freezing was proposed by Joslyn in the early 1940's (Hohl and Smith, 30), but, although the sieved frozen vegetables were of excellent quality, they were less economical to produce and market than existing heat-sterilized products. Interest in this field has revived recently and has centered about dehydrofrozen products. Vegetable purees partially dehydrated or concentrated can be packaged and frozen more economically than the straight purees. They are more quickly prepared for use by heating with water and their utility is thus greater.

The combination of fermentation and freezing is also possible for the prepara-

tion of specialty products. It is known that partially fermented products are often more palatable than when completely fermented. Fruit juices particularly apple and grape, are quite pleasing when in the initial stages of alcoholic fermentation. Low alcohol effervescent apple juice and grape juice are consumed as prepared in the home and long have been distributed in Austria and Switzerland. The preservation of these products by heat processing or with the conventional chemical preservatives is not satisfactory but they may be preserved by freezing. Similarly, lightly fermented cucumbers in the initial stages of lactic fermentation are crisp in texture and of pleasing flavor. While these have been used in this form, commercial preservation so far has not been feasible. It is likely that suitable methods of combining initial lactic fermentation with freezing can be developed and lead to new types of relishes. Cabbage and other leafy vegetables, apples, cherries, and green tomatoes also may be prepared by a suitable combination of lactic fermentation and low temperature storage.

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CONSTITUTION

THE SOCIETY FOR ECONOMIC BOTANY

MAY 12, 1961, REVISED

PREAMBLE:

The Society for Economic Botany is organized to foster coordination and collaboration and to develop communication among the various fields of interest which are concerned with the past, present, and future uses of plants.

ARTICLE I. *Name.*

Section 1. This organization shall be known as The Society for Economic Botany.

ARTICLE II. *Definition and Objective*

Section 1. The field of economic botany is defined, for the purposes of this Society, as all activities which pertain to the past, present, and future uses of plants by man. It is recognized that this broad definition includes all or parts of the many established disciplines such as: agronomy, anthropology, archaeology, chemistry, economics, ethnology, forestry, geography, geology, horticulture, medicine, microbiology, pharmacognosy, pharmacology, in addition to the established botanical disciplines.

Section 2. The objectives of The Society are to foster and encourage scientific research on the uses of plants and to make the results of such research available to the scientific community through scientific meetings and the publication of a journal.

Section 3. The Society for Economic Botany is organized and operated exclusively for scientific purposes. Its activities are to be conducted on a non-profit basis. No part of the net earnings of The Society inures to the benefit of any private individual. In the event of the dissolution of The Society all of its assets and property shall be transferred to a corporation, fund, or foundation organized and operated exclusively for scientific or educational purposes and exempt from Federal income tax under the provisions of §501(c)(3) of the Internal Revenue Code of 1954 or the corresponding provisions of any subsequent revenue law.

ARTICLE III. *Membership.*

Section 1. Individual members. This Society shall include: annual members, life members, and patrons.

Section 2. Institutional members. Public and private institutions, foundations, and industrial organizations may become members. Classes of institutional members shall include affiliate and sustaining members.

ARTICLE IV. *Officers and Councilmen.*

Section 1. The officers of this Society shall consist of: a President, Secretary, and Treasurer.

Section 2. There shall be six Councilmen elected from the membership of The Society, to serve terms of three years each, two of whom shall be elected each year. The Council shall elect its own chairman annually.

Section 3. Officers and Councilmen shall hold office until their successors are elected and assume their duties.

ARTICLE V. *The Council.*

Section 1. The Council, as provided for in Art. IV, Sec. 2, shall be the governing body of The Society, and shall have power to act on all matters petaining to The Society.

Section 2. The Council shall meet at the annual business meeting of The Society and at other times when deemed necessary by the Chairman of the Council.

Section 3. One-half of the members of the Council shall constitute a quorum for the transaction of business.

ARTICLE VI. *Election of officers and Councilmen.*

Section 1. A nominating committee shall select a candidate for each office. A mail ballot shall be distributed not less than three months before the Annual Meeting and shall provide for a write-in vote for each office.

Section 2. Officers and Councilmen shall be elected by mail ballot. The votes shall be tallied as provided for in the By-Laws, A pluraiity vote shall elect.

ARTICLE VII. *Branches.*

Section 1. For the purpose of developing local interest in any respect of economic botany, The Society through its Council may authorize regional, state, or local branches.

ARTICLE VIII. *Committees and Secondary Officers.*

Section 1. Standing committees may be established by By-Laws or by action of the Council.

Section 2. The positions of editor, librarian, and other secondary officers may be established by By-Law or by action of the Council.

Section 3. Special committees may be authorized by action of the Council or by plurality

vote of the members present at any regular meeting of The Society.

ARTICLE IX. *Meetings of The Society.*

Section 1. The Society shall hold an annual business meeting, the time and place of which shall be determined by the Council.

ARTICLE X. *Publications of The Society.*

Section 1. The official journal of The Society shall be ECONOMIC BOTANY beginning with Volume 13, 1959.

ARTICLE XI. *Amendments.*

Section 1. This constitution may be amended in the following manner: the proposed change must be submitted in writing to the Secretary, supported by the signatures of not less than five members in good standing at least three weeks prior to an annual meeting. Such proposal shall be submitted at the annual meeting. A copy of the proposed amendment shall be supplied to each member. At the time of the next annual election a copy of the proposed amendment shall be mailed to each member with the ballots. Votes on the amendment shall be returned with the election ballots. Two-thirds of the ballots cast must be in the affirmative for the amendment to be adopted.

ARTICLE XII. *Ratification.*

Section 1. This constitution drafted by the interim committee on organization shall go into effect when accepted by the pro-tem Council.

BY-LAWS

ARTICLE I. *Order of Business.*

Section 1. The following order of business shall be observed at all annual meetings unless set aside by vote: (1) Call to order; (2) Reading of the minutes of the previous meeting; (3) Reports of officers and committees; (4) Communications and resolutions; (5) Unfinished business; (6) New business; (7) Adjournment.

ARTICLE II. *Classes of Membership.*

Section 1. Individual Members.

Subsection a. Annual Members. Persons who are interested in any aspect of economic botany and who shall pay dues as decided by the Council.

Subsection b. Life Members. Persons interested in the purposes of The Society, who shall pay one hundred dollars ($100.00).

Subsection c. Patrons. Persons interested in the aims and objectives of The Society who contribute two hundred dollars ($200.00) or more to its support.

Section 2. Institutional Members.

Subsection a. Affiliate Members. Institutions which support The Society by annual contributions of one hundred dollars ($100.00).

Subsection b. Sustaining Members. Institutions which support The Society by annual contributions of two hundred and fifty dollars ($250.00) or more.

ARTICLE III. *Voting Privileges.*

Section 1. Only annual members, life members, and patrons shall be entitled to vote.

ARTICLE IV. *Reception into Membership.*

Section 1. All applications for membership shall be acted upon by the Membership Committee, subject to review and action by the Council.

ARTICLE V. *Election of Officers and Councilmen.*

Section 1. Only voting members shall be eligible to hold office in The Society.

Section 2. The Council shall select a Nominating Committee of three from the membership at large at least four months before the annual meeting.

Section 3. The Nominating Committee shall obtain the written consent to serve from all nominees before the names are placed on the ballot.

Section 4. Ballots shall be sent to all voting members three months before the annual meeting. Ballots shall be returned to the Secretary and must reach him not less than ten days before the annual meeting.

Section 5. The Chairman of the Council shall appoint three tellers to tally the votes. The results will be announced at the annual meeting.

Section 6. If for any one office, a write-in candidate receives 25 or more votes, election for that office will be held at the annual meeting.

ARTICLE VI. *Terms of Office.*

Section 1. The term of office for the President shall be one year.

Section 2. The term of office for the Secretary shall be two years.

Section 3. The term of office for the Treasurer shall be two years.

ARTICLE VII. *Duties of Officers.*

Section 1. The President shall conduct the business meeting and deliver an address at The Society's annual meeting.

Section 2. The Secretary shall keep a record of the proceedings of The Society and of the Council and conduct their correspondence.

Section 3. The Treasurer shall receive, expend, and deposit all moneys belonging to The Society as directed by the Council. He shall keep a record of all receipts and expenditures of The Society and make all payments by check. During temporary absences of the Treasurer, the Chairman of the Council shall assume his duties.

Section 4. The Council shall arrange for meetings of The Society and for exhibitions and tours. It may appoint subcommittees from its members or committees from The Society at large for specific purposes. It shall consider the formation of branch societies and shall act on all petitions for membership. If a vacancy occurs in any office of The Society, the Council shall fill the vacancy by appointment for the unexpired term.

ARTICLE VIII. *Payment of Dues.*

Section 1. The fiscal year of The Society shall begin on the first day of January.

Section 2. Membership dues include $6.00 annually for the publications of The Society.

Section 3. Members whose dues have not been paid by October 1 shall be considered delinquent. They will not be entitled to receive the publications or other benefits of The Society until arrears are paid.

Section 4. The names of all members whose dues have not been paid for one year shall be dropped from the rolls of The Society.

ARTICLE IX. *Secondary Officers.*

Section 1. The Council shall appoint an editor and at least five editorial board members, and may appoint such other secondary officers as may be needed.

ARTICLE X. *Publications.*

Section 1. The Council shall supervise the issuing of the publications of The Society.

ARTICLE XI. *Amendments.*

Section 1. A proposal to amend the By-Laws shall be submitted in writing to the Council by any five voting members.

Section 2. An amendment to the By-Laws may be adopted by a majority vote at any meeting of the Council, providing a notice in writing has been submitted to all members of the Council one month in advance of the meeting.

BOOK REVIEWS

Herbicides and the Soil. Edited by E. K. Woodford and G. R. Sagar. 88 pp. illus. Blackwell Scientific Publications, Oxford, 1961. 17s. 6d.

Herbicides and the Soil is a publication of the second symposium organized by the British Weed Control Council. Four subjects are amply discussed by reputable authorities in the field: "Microbiological Breakdown of Herbicides in Soils," by Audus; "The Effects of Herbicides on Soil Micoorganisms," by Fletcher; "Physicochemical Aspects of the Availability of Herbicides in Soils," by Hartley; and "The Persistence of Some Important Herbicides in the Soils," by Van der Zweep. An appealing feature of this publication is a discussion section following each topic.

Professor Audus effectively reviews the kinetics of herbicide disappearance from the soil through detoxification processes, and the part played by bacteria in these processes. The speaker, being intimate with his subject, presents important factual data. These data substantiate that, apart from small adsorption on soil colloids, the true course of detoxification for the phenoxyacetic acid (and other herbicides) has taken a typical enrichment form. This indicates that, under perfusate conditions at least, breakdown is almost entirely by proliferating microorganisms.

The review presented by W. W. Fletcher is restricted to the effects of herbicides on bacteria, actinomycetes, and fungi. The author is disturbed that the volume of research conducted on these topics was done long after the herbicides (and other biocides) had been on the market. The importance of these effects is realized when one considers that at least 35 million acres of land in the United States are sprayed annually with herbicides. In Europe, excluding the United Kingdom, more than 34.5 million pounds of herbicides were used in 1956. Professor Fletcher uses these figures to impress his readers with the obvious importance of determining the extent that herbicides affect growth of microorganisms in soils, as well as effects on various cyclic systems—carbon, nitrogen, mineral, and sulfur. The effects on soil microorganisms of 34 herbicides are discussed by Professor Fletcher.

"Physicochemical aspects on availability of herbicides in soils," by G. S. Hartley, provides pleasant reading of highly technical subject matter. The reader gains insight concerning the complications that non-uniform porosity, alternating drainage, and evaporation are likely to introduce in the leaching process of herbicides in soil. Ample evidence is cited to substantiate that moisture status of soils prior to application is just as important to herbicide behavior as subsequent rainfall. Simply, solubility of herbicides is more important than expected when one considers the amount of rainfall needed to dissolve an applied dosage.

Dr. Van der Zweep makes the reader aware of our primary need to control the persistence of herbicides rather than to suffer the consequences. He points out that research on leaching behavior, on interactions between herbicides and chemicals already in the soil, on breakdown by microorganisms, on vapour loss, and inevitably on the unavailable fractions held inactive in soil, will be necessary before we can become masters of the persistence of herbicides in soils.

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Drogenkunde. H. A. Hoppe. 7th ed. 1231 pp. Cram, De Gruyter & Co., 1958. 78DM.

This manual of vegetable and animal raw materials which are used for medicinal, veterinary, and pharmaceutical purposes is in its seventh revised and expanded edition. It purports to include all of the naturally occurring drugs presently listed in the pharmacopoeias and collateral volumes of the United States, Great Britain, Germany, France, Russia, and Switzerland. The book

is arranged into five main parts. The first and largest (968 pages) deals with plant drugs or botanicals; Part II (46 pages) deals with animal drugs; Part III (44 pages) gives the geographical sources of the more important plant drugs; Part IV (55 pages) lists the chemical constituents of plants such as volatile oils, balsams, coloring principles, fixed oils and fats, tannins, gums, resins, latex, saponins, mucilages, waxes, and various others of a minor nature; Part V gives 5½ pages of equivalents of important terms in German, English, French, Portuguese, and Spanish. A general bibliography of 2½ pages limited largely to German texts is followed by four pages of journals. An index of 114 pages in three columns completes the book.

Each item of Parts I and II appears in a typical monograph form. For each drug are listed the scientific name, family, geographical source, part used (i.e. bark, rhizome, ambergris), trade name or other designated name or title, official sourcebook, active constituent(s) (here appear the alkaloids and glycosides, which are absent from the list in Part IV), and remarks concerning the medicinal usage or application. In a few instances other botanical species with similar medicinal properties may be listed. An up-to-date bibliography follows the monographs of the more potent and significant drugs as in the case of Digitalis, Aspidium (Dryopteris), Rauwolfia, and Rheum (Rhubarb).

This handbook is most extensive in its listings of medicinally and pharmaceutically used drugs. It certainly should be in the hands of all librarians, particularly those upon whom calls are made for information concerning medicinally and economically used plants. I dare say that the book will be kept not too far from the telephone.

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Plant Growth Regulation. Fourth International Conference on Plant Growth Regulation. 850 pp. illus. The Iowa State University Press, Ames, Iowa, 1961. $8.50.

This volume constitutes the proceedings of the Fourth International Conference on Plant Growth Regulation, which was held at the Boyce Thompson Institute for Plant Research in Yonkers, New York, in August, 1959. It includes 63 reports by 97 contributing authors. Although in such a conference it is difficult to have a central theme, the reports have been grouped under several categories. Included among these are naturally occurring plant growth substances (7 reports, 115 pages), the mechanisms of auxin activation and inactivation (6 reports, 73 pages), the synthetic growth regulants (18 reports, 242 pages), the gibberellins (18 reports, 198 pages), other plant growth regulators (8 reports, 119 pages), and improvement of growth regulator formulation (3 reports, 27 pages). Two introductory papers on general concepts of plant growth regulation and a final paper on the probable future of auxinology complete the volume. The reports vary in content all the way from the presentation of new data to new interpretations of the old. They include comments made and questions raised by the participants at the time the papers were presented.

On the whole the reports are well written and the book is well edited. Liberal use of tables, figures, charts, and photographs adds to the clarity of the presentations. An additional feature which increases the utility of this compilation of papers is an extensive subject index. The book should be a valuable addition to the library of those individuals concerned with teaching or research in the field of plant growth regulators. The unfortunate thing about it is the long interval of time between the conference and the appearance of the volume. It is most appropriate that this book was dedicated to the late Dr. Percy W. Zimmerman, one of the pioneers in the field of plant growth regulators, who had been designated honorary chairman of the conference.

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Fats and Oils: An Outline of their Chemistry and Technology. H. G. Kirschenbauer. 2nd ed. 240 pp. illus. Reinhold Publishing Corporation, New York, 1960. $7.00.

This small volume provides a simple and up-to-date outline of the fundamentals of

the chemistry and technology of fats and oils. It is composed of eight chapters, three appendixes, and an index. Noteworthy features include the numerous well selected references to literature, flow diagrams for a number of the more important processes discussed in the text, and a table which gives technical data (source and characteristics including specific gravity, refractive index, melting point, iodine value, saponification value and titer) for some 150 fats and oils.

The first four chapters discuss the occurrence, formation, and metabolism of fats; the constituents and components of fats; the structure and composition of fats; and the physical and chemical properties and reactions of fats and fatty acids. All this is accomplished in the space of only 40 pages! Obviously the treatment accorded each topic is necessarily extremely brief. This leads to over-simplification and even to inaccuracy. Nevertheless a great deal of pertinent, general information is provided, and the exceptionally well selected references to the literature given at the end of each chapter afford an opportunity to obtain more detailed information. The next chapter, on analytical methods (21 pages), lists approximately 100 analytical tests or methods arranged alphabetically from Acetyl value to Wiley melting point. The information supplied is not sufficient to enable the reader to perform the tests, but generally it includes a definition and sufficient material to enable the reader with some technical background to recognize the basic procedures or principles involved in the determination of the value or characteristic discussed.

Much the longest chapter (103 pages) is devoted to the technology of fats and oils and their derivatives. In this chapter are outlined the important aspects of processing, e.g., production, splitting, hydrogenation, sulfonation, and distillation; of products, e.g., soaps, surfactants, protective coatings, and lubricants; and of applications in specific industries, including the textile, oilcloth, cosmetics, pharmaceutical, leather, candlemaking, and tin-plating industries. The next chapter (20 pages) discusses briefly the source, method of production, and some statistical data for about two dozen of the most commercially important fats and oils. The final brief chapter (3 pages) deals with the important vegetable and animal waxes.

The emphasis in this volume is on the practical technology of production, processing, and utilization of fats and oils. The book will probably be of most value to administrative and sales personnel and technologists and perhaps to chemists, engineers, students, and scientists in other fields who have need of some knowledge of the language, materials, and methods of the fats and oils industry or who wish an introduction to it.

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The Australian Environment. Commonwealth Scientific and Industrial Research Organization. 3rd ed., rev. 151 pp. Illus. Melbourne University Press; New York: Cambridge University Press, 1960. $6.00.

Continuing demand for this excellent summary volume has made a revised third edition necessary. The original edition was prepared for delegates to the Specialists Agricultural Conference on "Plant and Animal Nutrition in Relation to Soil and Climatic Factors," held in Australia in 1949 as one of the series of British Commonwealth Specialist Conferences. It aimed at "providing delegates with some understanding of the history and present stage of development of the plant and animal industries of Australia against the background of their environment."

The chapters of the original book have been individually revised by their authors, all Australian specialists. The nine chapters are "Physical Geography" (E. S. Hills), "Climates" (G. W. Leeper), "Soils" (J. K. Taylor), "Development of Agriculture" (Sir Samuel Wadham), "Water and Irrigation" (J. A. Aird), "Vegetation" (J. G. Wood and R. J. Williams), "Pastures" (C. S. Christian and C. M. Donald), "Field Crops" (H. C. Forster et al.), and "Sheep, Cattle and Pigs" (R. B. Kelley). Suitable halftones illustrate each chapter, and there are also appropriate tables and outline maps throughout the book. Double-page fold-in maps in color covering the soils, vegetation (based on reconnaissance mapping), and

pastures of the continent are also included, and of these the last two are new with this edition.

Economic botanists interested in Australia will find the chapters on vegetation, pastures, and field crops particularly pertinent and suitable as introductions to these fields. Here will be found succinct treatment of such topics as vegetational categories and their characteristics, descriptions of principal plant communities, and correlation of vegetation forms with environmental factors; principal features of Australian pastures, classification and description of pasture zones, and trends in pasture development; wheat and winter cereals, flax, orchards (apples, pears, stone fruits, citrus, bananas) and vineyards, vegetables (principally potatoes and green peas), and other field crops (including sugarcane, maize, grain sorghum, rice, cotton, tobacco, and peanuts). Additional readings are listed at the end of each chapter.

All agricultural scientists who find this kind of specialized background knowledge of Australia desirable in a compact form should thoroughly appreciate *The Australian Environment*.

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Politics and Grass: The Administration of Grazing on the Public Domain. Phillip O. Foss. 236 pp. illus. University of Washington Press, Seattle, 1960. $4.50.

Politics and Grass is a brave attempt to bring together the story of the public domain in the United States—its history and also the public policies affecting its management and disposal. The author is neither a range management specialist nor a land administrator nor a rancher. He is a political scientist and at present a faculty member in the Department of Government at San Francisco State College. What the book lacks in the biological aspects of technical range management and livestock production is balanced out by the wealth of insight into why certain public land policies came into being and into their sociological and economic impact upon citizens of the public domain states.

This book considers the acquisition of the public domain, early land disposal policies, the Taylor Grazing Act, policy making in the Grazing Service and later Bureau of Land Management, a case study of a selected controversy over grazing permits, and the grazing fee controversy on the public domain. The author continually attempts to get behind the scene to determine why things happened as they did and how the various policies and laws affecting the public domain came about. He is very frank in reporting things as he finds or interprets them.

He is critical of many of the governmental policies affecting the public domain. "Unrealistic land-disposal policies resulted in crazy-quilt patterns of ownership, often in uneconomic units, and encouraged fraud, conflict, economic instability, overgrazing, and futile attempts at cultivation of submarginal lands." He suggests that "the 'free land' *had* to result in overgrazing. Cattlemen and sheepmen could not be expected to withhold stock from government range to prevent overgrazing when they knew that other stockmen would get the grass they left."

Mr. Foss quotes one Hibbard concerning the Homestead Act passed into law in 1862 —"The great weakness of the Homestead Act was, and is, its utter inadaptibility to the parts of the country for which it was not designed. The idea of the farm small in acres within the semi-arid regions was tenacious, but untenable. It was even vicious in its operation." To this the author adds, "The 160-acre tract may have been out of date at the time of passage of the act." "The old lawless West of range wars and conflicts between homesteaders and stockmen, and between cattlemen and sheepmen, was lawless not because it was populated by a peculiar breed of hyperaggressive and unscrupulous people, but because of political acts which resulted in land policies that were not suited to the region and that had the effect of encouraging conflict, insecurity, and disrespect of law."

The author points out the schemes used by stockmen to reserve grazing rights on the public domain for themselves but concludes that "this kind of finagling does not necessarily imply that the early stockmen were rogues or possessed of any particularly sinister or wicked intent. Most of the land so

manipulated was of such low productivity that homestead tracts were too small to provide a reasonable living. Consequently, stockmen and farmers were forced to supplement their homestead with 'free land' or go bankrupt."

The author reports that the range "rights" as handled today in the Bureau of Land Management "materially enhance the values of base properties, especially since the grazing fees have been consistently low." Nevertheless, he reports early opposition of stockmen against any grazing fee as follows: "Nevada stockmen, as well as some ranchers in other states, had built their livestock operators on the assumption that they would continue to enjoy free use of the federal range. Persons who had purchased ranch properties had done so assuming that the public lands would remain free. Ranchers also maintained that, since property values (and hence assessed values) were based on capitalized income, they had, in actuality, been paying property taxes on federally owned lands."

"To many of the stockmen of this area (the West), the federal range is an integral part of their ranching operation. Their private holdings may be of little value without continued access to the range. The range is not usually an extra or bonus piece of pasture; it is more likely to be a necessary part of the ranching unit. Grazing permits are ordinarily capitalized into the value of the ranch so that if permits are stabilized a ranch buyer actually pays for both the private and public lands contained in the ranch unit."

The author suggests that range deterioration has been slowed down but not stopped entirely and that range improvements are needed. He suggests that the meager appropriations for such are associated with the stockmen's insistence on low grazing fees. "Stockmen are desirous of improving the range, but if such improvement comes at the cost of closer regulation and increased fees they seem willing to forego it." The author concludes that two praiseworthy accomplishments of the Taylor Grazing Act were to "stabilize the livestock industry dependent upon the public range" and "the withdrawal of the public lands from the possibility of further unsuccessful homesteading and resultant destruction of the range."

"The principal decision-maker of the federal grazing activity include the advisory board members, leaders of the stockmen's associations, a small number of congressmen, and some members of the federal grazing bureaucracy. . . . There are few groups of comparable size, if any, which are as politically powerful as are the western stockmen." The author concludes that other land-users would play an increasingly greater role in formulating public land use policies.

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Studies on the Physiology of Bamboo with Reference to Practical Application. Koichiro Ueda. 167 pp. illus. Resources Bureau Reference Data No. 34, Resources Bureau, Science and Technics Agency, Prime Minister's Office, Tokyo, 1960.

The author is professor of forestry at Kyoto University, director of that university's Kamigamo Experimental Forest, and Japan's outstanding authority on the production of bamboo. Prof. Ueda has devoted some 20 years to bamboo research.

The reader who searches extensively for information on the biology and agriculture of bamboo will soon conclude that, in spite of a large number of titles, recent literature offers too little that has not appeared before. He will also conclude that, although considerable information is available about caespitose species, few western-language contributions deal with rhizomatous bamboos. Prof. Ueda's book is refreshing in that it is based largely on the author's personal experience and original research. Part of the information published here has appeared previously, but only in Japanese, and some has never appeared before.

The author deals primarily with the two bamboos, both rhizomatous species, of greatest commercial importance in Japan, *Phyllostachys bambusoides* Sieb. et Zucc. (as *P. reticulata* auth. Jap.) and P. *pubescens* Mazel ex. H. de Leh. (as *P. edulis* H. de Leh). He makes brief reference to other Japanese bamboos and to some Indian species with which he has had first-hand experience. The fact that *P. bambusoides* and other species of *Phyllostachys* are well

adapted to cultivation in southeastern United States makes this book of special appeal to American readers.

Prof. Ueda's monograph would have been more appropriately titled *Biology of Bamboo* or simply *Bamboo*, for it contains relatively little on bamboo physiology, but a vast amount of other information about this group of plants. About half of the book is devoted to factors related directly or indirectly to growth and development, mainly of culms and rhizomes. The data and discussions are limited largely to gross physical qualities; little attention is devoted to anatomical details. Many of the data are purely descriptive, e.g., tables or graphs which indicate the relation between culm diameter and culm length, the relation between culm diameter and fresh weight of culms, and the relation between culm size and leaf area and weight. Several maps show the extent and yearly extension of rhizome systems and their associated culms. Tables and graphs also show such factors as the relation between daily elongation of culms and daily maximum temperature and precipitation, and seasonal variation in starch content of culms and rhizomes. Short chapters cover cytological studies and the flowering of bamboo. The remainder of the book is devoted largely to cultivation and management of bamboo in Japan.

In general this work lacks depth and should not be considered as a final answer to the bamboo-information problem, but it will provide a valuable basis for further study of this group of plants. The book would have benefited greatly from editing by one proficient in the use of English. Many tables and parts of the text must be studied with great care for the reader to gain an accurate understanding of the author's presentation. Nevertheless, Prof. Ueda is to be commended for bridging the language barrier and making available to the western world this valuable contribution. The book, which includes numerous tables, graphs, drawings, and photographs, is appropriately printed on paper manufactured from bamboo pulp.

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Pulp and Paper: Chemistry and Chemical Technology. Vol. 1: Pulping and Bleaching. James P. Casey. 2nd ed. 580 + 95 pp. illus. Interscience Publishers, Inc., New York, 1960. $25.00.

This is volume one of a proposed three-volume revision of the first edition, which was published in two volumes in 1952. The reader familiar with the earlier edition will have no difficulty in finding his way through the second. Chapter 1 is devoted to "Cellulose and Hemicellulose," Chapter 2 to "Lignin," Chapter 3 to "Pulpwood," Chapter 4 to "Pulping," and Chapter 5 to "Bleaching." About 60% of the volume is included in the chapter on pulping, which gives detailed accounts of sulfite, alkaline, and mechanical pulping systems. Semi-chemical pulping systems, increasingly important processes which involve softening of wood by chemical treatment followed by mechanical disintegration, are described. This chapter includes a short account of "whole wood-fiber manufacture," involving pulping processes which reduce wood to a fibrous or particle stage with minimum removal of lignin for manufacture of particle board, insulation boards, hard board, etc. It also discusses briefly the pulping of old papers, rags, cereal straw, esparto, hemp, jute, sugarcane bagasse, cornstalks, and bamboo.

Like the first edition, the second will prove a valuable reference tool. The chief virtues of this work are its excellent organization and detailed index. The book is so well organized that the reader familiar with the text can often go directly to the desired section without reference to the index. The extensive list of references (more than 1500), chiefly to the literature of pulp and paper technology, will be of great value.

Casey's work, although not well adapted to the individual personal library, should be a useful addition to the technical library of any institution concerned with pulp and paper technology. The new edition is undoubtedly more valuable than the first but not sufficiently so at the quoted price to entice one who has the first edition available.

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Weed Identification and Control in the North Central States. D. Isely. 2nd ed. 400 pp. illus. Iowa State University Press, Ames, 1960. $4.95.

This book has grown from the weeds course that Dr. Isely, professor of botany at Iowa State University, has taught "for some years." It is designed "to help students know something about (1) the importance, behavior, and identity of important and common weeds, (2) methods for determining unknown weeds, (3) the basic principles of weed control, and (4) recent advances in herbicidal weed control as they apply to important weed problems." The first edition of *Weed Identification and Control*, a 152 page book without illustrations, appeared in 1958. The present addition has 400 pages, the increase accounted for in large part by the inclusion of 159 full-page plates illustrating about 230 weeds and of a 42 page key to about 320 "well known" weeds.

The book is divided into five parts: (1) "Weeds, Crops, and Human Beings" (32 pages), including discussion of the nature, importance, and distribution of weeds, of weeds and agricultural seed laws, of scientific names, and of plant structure and associated technical terminology; (2) "Classification of Weeds by Family Characteristics" (209 pages), with considerable and laudable emphasis on the earmarks of families as a means of increasing student familiarity with these taxa; (3) "Identification of Weeds from Flowers and Leaves" (46 pages), containing the above-mentioned key, which was adapted from the key prepared by Dr. Isely for *Weeds of the North Central States* (North Central States Regional Publication 19. 1954); (4) "Poisonous Weeds" (7 pages); and (5) "Weed Control" (73 pages), that part of the text that has been most enlarged, revised, and updated—as would be expected because of rapid developments in this field in even the short time since the first edition.

The book represents a job well done. Its excellently organized, accurate, up-to-date, and lucid presentation of data will be valuable to those who seek information on weeds and their control in north central United States—and in adjacent areas as well, not only because of similarity in weedy floras but because of the emphasis that Dr. Isely has placed on principles of weed control.

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Plants that Changed the World. Bertha S. Dodge. 183 pp. illus. Little, Brown and Co., Boston and Toronto, 1959. $3.50.

Notwithstanding the many products of synthetic laboratories available today, man's dependence on plants has tended to increase with the progress of civilization, and at the present time, more than ever before, there is a growing demand for new or better sources of useful plant products. This is particularly true in the drug industry. Before the chemist can carry out his investigations of the valuable substances synthesized by plants, however, there must be plant collectors and botanists who are able and willing to search out and study the plants themselves.

This very readable book tells the story of some of the plant products that have made history and of the men who sought them out in the far corners of the earth. The author has gone to the original sources for her information, and not the least valuable aspect of the book is this bringing together in one place of material not readily accessible to the average reader.

The ten chapters are as follows. "Lilacs and Lilies" is a general introduction and emphasizes the debt we owe to plants and to the plant hunters who, following sometimes the most nebulous of clues and enduring untold hardships, have finally succeeded in bringing back to our laboratories the many new plant products that play such an important part in our modern society. "Joseph Banks and the Breadfruit" recounts the familiar story of the breadfruit and mutiny of the Bounty. "Food for the Gods" relates the early history of cacao in both the New World and the Old. "The Fever Bark Tree" tells the story of quinine and of the many men who played a part in its fascinating history, among them Jussieu, Mutis, Richard Spruce, and Charles Ledger. "Kalaws and Kings" deals with chaulmoogra oil and the work of Joseph Rock. "The Weeping Tree" emphasizes the role of La Condamine, Spruce, Wallace, and Wickham in the development of the rubber industry

and the rubber plantations of the world. "Enough Rope" is an account of Manila hemp and its introduction from the Philippines into Central America. "The Big Leaf" is a story of the wax obtained from the carnauba palm and, more recently, from the cauassú plant, the "Big Leaf" of the Amazon basin. "Life from the Flying Death" summarizes the discovery of curare and the identification of the plants utilized. Here again we learn about some of the men responsible: von Humboldt, the Schomburgks, and, in recent years, Richard Gill. "A Look Ahead" includes a brief account of Rauwolfia and gives an optimistic view of the future now that "plant products, whether in commerce or medicine, have at last come into their own."

A bibliography of the 32 works from which the author obtained her material is appended, and there is an adequate index. The illustrations by Henry Bugbee Kane add much to the attractiveness of the volume.

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A Bibliography of Eastern Asiatic Botany. Supplement I. E. H. Walker 552 pp. American Institute of Biological Sciences, Washington, D. C., 1960. $18.50.

As every scientist is aware, bibliographies are among the most useful research tools. Of the few botanical bibliographies available, one of the most oustanding is *A Bibliography of Eastern Asiatic Botany* (1938), which has become a model of similar regional bibliographies. Now this distinctive work is brought up-to-date in a supplement by the junior author of the original work. Workers will find this supplement as useful as the original and perhaps even more satisfactory in certain respects.

Like the original bibliography, this supplement is primarily in English, but it has an additional and highly desirable feature: the inclusion of the original Chinese, Japanese, and Korean titles as published in oriental characters, in addition to translations of these titles. Russian titles are transliterated into Roman letters and are also translated. Chinese and Japanese characters are added for all oriental authors.

This supplement, covering the period 1937-1958, is more than half as extensive as the original work. It contains over 11,000 entries as compared with over 21,000 in the original. The area covered is the same as in the original, mainly eastern Asia but with major papers on southern Asia also included. The term botany is interpreted to cover most publications dealing with plants in the area: systematic botany, vegetation, phytogeography, ecology, economic botany, medicinal botany, plant pathology, historical botany, plant exploration, etc. The plant kingdom is covered from bacteria and myxophyta to the compositae. The author, however, notes the difficulty of complete coverage of all literature is this area because of situations resulting from wartime disruptions.

Like the original bibliography, this supplement will prove to be a useful reference work not only to the botanist but also to the horticulturist, pharmacologist, librarian, anthropologist, and ethnologist. The usefulness of the work is greatly enchanced by the presence of not only a list of authors and titles, but also many other desirable accesories, including a brief but often critical annotation to every entry, and a reference list of over 800 serial abbreviations. Perhaps the most important and useful feature is the extensive subject index, comprising a general index, a geographic index, and a systematic index. With the aid of this, a special bibliography on many subjects, such as bamboo, cotton, cultivated plants, dye plants, economic plants, fiber plants, weeds, medicinal and drug plants, and oil yielding plants, to name a few as given, can be compiled in a few minutes. The time saved by the many workers who will have chance to consult this work is beyond comprehension.

This book is well printed and well bound. In such an extensive work, and in one employing, besides the western languages, types of three oriental languages, typographical and editorial errors are necessarily unavoidable. A separate supplementary list of "Changes to be made in Japanese and Chinese items," listing 82 such corrections, is available with the book. This list, however, is not exhaustive. For instance, on the title page, "Supplement" is rendered in the Chinese characters *ts'ên-pu* which are correctly transliterated into the Japanese pronounciations as *zóho* but, incorrectly into the Chi-

nese as *pu-i*. The text should be carefully combed for these and other errors, and a full list of corrections should be made available with every copy of the book.

It is beyond saying that such an important reference work is a must item for nearly every library. To botanists, especially those working in the fields of systematic botany and economic botany, I would recommend this book as a worthy one. We should all be grateful to Dr. Walker for providing us with such a useful reference work. It is truely a distinctive piece of bibliographic study, well designed and well executed.

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Yearbook of Forest Products Statistics, 1960. Food and Agriculture Organization of the United Nations. 160 pp. FAO, Rome, 1960. $2.50. (sales agent: International Documents Service, Columbia University Press. New York)

The fourteenth *Yearbook of Forest Products Statistics* presents information on production and trade in forest products during 1958 and 1959 for 159 countries. The data presented are estimated to cover more than 95% of the world output of the principal forest products. Thus, FAO is close to attaining its original objective of providing comprehensive world coverage of forest products statistics.

Statistical material on production and trade is divided into sections concerned with roundwood, processed wood, pulp and paper products, and forest products other than wood. A section is devoted to trade in forest products, and a general section contains such data as per capita consumption of forest products and land and forest areas of the world. Although the 1960 edition of the *Yearbook* contains more information than any of its predecessors, the statistics for many countries and regions are incomplete. This is particularly true for most African, South American, and southeast Asian countries where no reliable estimates are available of the quantity of wood produced and used by local inhabitants. While the statistics in the *Yearbook* are incomplete in some respects, substantial progress has been made in improving the coverage of the data presented. Since 1947, the first year the *Yearbook* was published, coverage has been expanded from 75 to more than 125 reporting countries. In addition, countries in all parts of the world have improved their statistical reporting services, and the outlook for further improvement is good. Part of the past improvement reflects the efforts of the Food and Agriculture Organization to improve world forestry statistics through its Technical Assistance Program.

The *1960 Yearbook of Forest Products Statistics* is the most authoritative source of information available on world production and trade in forest products. It is an indispensable tool for those interested in the world forestry situation.

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